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MODEL OF AIRCRAFT NOISE ADAPTATION

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SUMMARY

A series of studies is being conducted at Langley Research Center for development of an aircraft noise adaptation model which would account for much of the variability in the responses of subjects participating in human response to noise experiments. This paper presents a description of the model development to date. The principal concept of the model is the determination of an "aircraft adaptation level" which represents an annoyance calibration for each individual. Also given in the paper are the results of a human response to aircraft noise experimental study which utilized subjects from both the Hampton - Newport News, Virginia area and the J. F. Kennedy Airport area of New York City. There was some variability in the annoyance responses of the two groups, with the New York subjects rating a given noise as more annoying than the Virginia subjects.

The results of the study indicated that the aircraft noise adaptation model accounted for some of the differences which occur between subjects in making annoyance judgments of noise stimuli. The measured aircraft noise adaptation level can explain why different people will give equal annoyance ratings to noises which are different in level by 15 dB. An individual's aircraft noise adaptation level was partially predictable from various attitude-personality variables which account for some of the differences which occur between subjects in making annoyance judgments. The noise level of the stimuli was found to be the single most important parameter in predicting annoyance reactions to aircraft noise.

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INTRODUCTION

Air transportation and the associated noise impact in airport communities has resulted in concern and often annoyance of residents about this form of environmental intrusion. In order to determine the aspects of aircraft noise that cause annoyance, laboratory studies are often utilized to assess the importance of various physical aspects of noise on subjective response. However, laboratory studies have generally resulted in restricted conclusions due to a large variation in annoyance responses provided by different people to even a single aircraft noise. This problem of response variation is, of course, amplified when different aircraft noises are considered or the effects of aircraft noise are obtained through community investigations or surveys. For example, the problem of response variability makes it difficult, if not impossible, to provide accurate information for comparison of the relative annoyance of various aircraft, or for evaluation of various optimization schemes for the reduction of aircraft noise through aircraft/airport operations.

The purposes of this report are to (1) describe an aircraft noise adaptation model currently being developed to account for the response variation in laboratory or survey research, and (2) present results of an initial investigation for evaluation of the model. Since the questions and hypotheses of the initial investigation are model related, the next section provides a resume of the noise model before the specific objectives of the study are enumerated.

Traditional Aircraft Noise Studies

Traditional laboratory and community survey investigations of the effects of aircraft noise on people have used the type of experimental design displayed in figure 1. Through use of an annoyance scale as shown on the right of the figure, a person indicates an annoyance response to various aircraft noises.

The researcher then relates the strength of annoyance response to physical measurements of the aircraft, e.g., in A-weighted sound pressure level. The major problem with this approach is that annoyance responses of different people vary widely even for the same aircraft noise. In community surveys, for example, only 25 to 50 percent of the annoyance response variability has been accounted for by the physical measure (e.g., ref. 1).

Aircraft Noise Adaptation Model

The problem of response variability can be approached using the experimental design displayed schematically in figure 2. Central to the model is the concept of "aircraft noise adaptation level" which represents an "annoyance calibration" level for each subject. This calibration level approach represents a modification of classical psychophysics theory as discussed in reference 2. Basically, the model proposes that a specific annoyance response a person expresses is a function of the interpretation of an aircraft noise by a person relative to his frame of reference or aircraft adaptation level for aircraft noise. Quantitatively, the aircraft adaptation level represents for each subject the transfer function (gain, sensitivity, modulation, etc.) between aircraft noises and annoyance responses.

Components of Aircraft Noise Adaptation Model

Figure 3 displays the initial assumptions as to the determiners of a person's aircraft adaptation level. Both physical and psychological factors are considered to influence the person's frame of reference regarding aircraft noise. The primary physical factors include the aircraft noise impact in the area in which the person resides (usually specified in terms of NEF or L_{dn}), and the street noise of the immediate neighborhood. Also, other environmental factors (vibration, temperature, etc.) may be important for a

comprehensive model development. On the other hand, there are a host of potential psychological factors that could influence this framework which include aircraft attitudes, noise sensitivity, environmental sensitivity, and various personality factors. Each of these potential psychological determiners of aircraft adaptation level was investigated within the present study and is discussed at length in subsequent sections. These factors represent a potential source for explanation of annoyance response variation in the prediction of annoyance. The components of the noise model displayed in figure 3 can be mathematically expressed as:

$$AR = TS \times AA \tag{1}$$

where

$$AA = f(TS, AN, ST_N, AT, NS, \ldots) \tag{2}$$

and

AR - Aircraft Annoyance Response

AA - Aircraft Annoyance Adaptation Level (frame of reference)

TS - Test Stimuli (aircraft noises)

AN - Aircraft Noise Exposure

ST_N - Street Noise Level

AT - Aircraft Attitudes

NS - Noise Sensitivity

The exact mathematical relationship (equations 1 and 2) between components of the noise annoyance response model is hypothetical at this time. A critical consideration in defining these mathematical relationships is measurement of the aircraft adaptation level. This study has provided initial information for formulation of the equations based on empirical results. Due to the difficulty associated with definition and measurement of an individual's aircraft noise adaptation level, a two-step approach was used for analysis of

the concept. The first step involved a direct approach as described in the method section. This step involved obtaining annoyance responses from each person relative to a standard noise in a fashion similar to calibration of physical equipment. The second step involved model definition through the collection of various physical and psychological information shown in figure 3. Through successive iterations of information from each step, both the measurement and definition of the model should evolve.

OBJECTIVES

The general objective of this study was to account for the variability in annoyance responses of different people to aircraft noise and thus validate an aircraft noise adaptation model. In order to study this variability, detailed information was collected from each participant in the study including annoyance reactions to a wide range of aircraft noises, measured aircraft noise adaptation levels, and various attitude-personality measures. Consistent with development of the aircraft noise adaptation model, these different sources of information were combined to determine whether or not the annoyance response variability between people was predictable.

To assist in accomplishing the general objective of the study, several subobjectives were undertaken. These objectives included:

1. A description of the annoyance responses associated with a wide range of aircraft noises.

2. Assessment of the ability to measure an aircraft noise adaptation level for an individual.

3. A determination of the ability to improve the prediction accuracy of annoyance responses through considering each participant's aircraft noise

adaptation level in the annoyance prediction.

4. An assessment of the ability of the attitude-personality measures to explain the variance beyond that accounted for in number 3.

5. An assessment of the relative importance of the various physical and psychological factors as structured determiners of an individual's aircraft noise adaptation level.

ABBREVIATIONS

The following abbreviations have been used in the present investigation. Additional descriptive information concerning frequency weightings and computational procedures for noise scales and indices can be found in references 3 and 4.

L_A - A-weighted sound pressure level (A-level)

L_C - C-weighted sound pressure level (C-level)

L_{D1} - D-weighted sound pressure level (D_1-level) (converse of 40-noy contour)

L_{D3} - D-weighted sound pressure level; modified (D_3-level)

L_P - Overall sound pressure level

L_{PNE} - Effective perceived noise level

NEF - Noise Exposure Forecast

L_{dn} - Day/night level

AR - Aircraft Annoyance Response

AA - Aircraft Annoyance Adaptation Level (frame of reference)

TS - Test Stimuli (aircraft noises)

AN - Aircraft Noise Exposure

ST_N - Street Noise Level

AT - Aircraft Attitudes

NS - Noise Sensitivity

METHOD

The following sections address the test facility used for the investigation, subject information, and the experimental procedure used for testing including the exact noise characteristics that were presented to the subjects.

Test Facility

Monophonic recordings of various aircraft noises (described in a subsequent section) were reproduced on a high quality tape recorder. Although some tape hiss was audible on the original recordings, an acoustic filter with a rolloff at 6,000 Hz was used to reduce the extraneous noises. The aircraft noises were reproduced in the Exterior Effects Room (figure 4) of the Aircraft Noise Reduction Laboratory at NASA Langley Research Center. Six of the ten loudspeakers were used for presentation of noise to the subjects.

Subjects

A total of 109 subjects participated in the study. Table I indicates that these people varied in age, sex, location of residence, and hearing ability. The 80 residents of Virginia represented the main subjects of the experiment and were required to have no worse than 20 dB of standard normal hearing (ref. 5). The residents of New York participated in the study because of their interest in aircraft noise problems. The New York subjects were not excluded from participation in the study due to hearing ability. The hearing ability of the group would be considered "normal" for their age (see ref. 6).

Test Procedure

An average of eight subjects participated in the study during each test session which lasted approximately 4 hours. Each subject was audiometrically screened prior to arrival at the laboratory. Upon arrival at the laboratory, each subject completed consent forms (see Appendix A), and was briefed concerning the series of activities for the study. Table II lists the activities and the approximate time duration of each activity. Subsequent sections present a description of the tasks that a subject was requested to complete during each activity.

Annoyance threshold testing. - The initial portion of the test was used to obtain the measured aircraft noise adaptation level for each subject. The instructions for the task are reproduced in Appendix B. In this task, each subject used the method of constant stimuli to evaluate American National Standards Institute (ANSI), ref. 7, noises of 15-second duration, which ranged in A-weighted sound pressure level from 65 to 95 dB in 5 dB increments. As shown in figure 5, a subject was presented a particular ANSI noise, e.g., 65 dB, and asked whether the noise was "annoying" or "not annoying." Successive noises were presented and similar responses obtained for each noise. The seven noise levels (65 to 95 dB) were randomized (without replacement) a total of four times so that a subject had to evaluate a total of 28 noises during this period of testing.

Figure 6 displays the type of analysis that was completed in order to obtain the measured aircraft noise adaptation level for each subject. The figure indicates the relationship of annoyance to noise level. The noise level evoking an annoyance response 50 percent of the time was then taken as the subject's aircraft noise adaptation level. For the example in figure 6, the person's measured aircraft noise adaptation level was an A-level of 75 dB.

Postthreshold testing was identical (except for noise presentation randomizations) to prethreshold testing. The reason for postthreshold testing was to assess the influence upon a person's aircraft noise adaptation level of the aircraft noises that occurred within the experiment.

Aircraft noise stimuli. - The aircraft noises that each subject evaluated are shown in the experimental design, figure 7. The aircraft noises varied in (were factorial combinations of) aircraft type, noise level, and operation for a total of 56 different stimuli which were randomized for each group of subjects. All noises were recorded at locations near the Federal Aviation Administration FAR-36 noise certification measurement locations for takeoff and approach operations. A detailed description of the stimuli is reported in reference 8.

In this portion of the experiment, annoyance judgments of various aircraft noises were obtained. The instructions for the task are reproduced in Appendix C. The category scale which subjects used to evaluate each noise was unipolar, continuous, and contained nine-scalar points or demarcations.

Attitude tests. - During two different activity periods, each subject was requested to supply various attitude information through a series of paper and pencil tasks. This information was collected primarily to determine the relative importance of various psychological factors for the construction of an individual's aircraft noise adaptation level. The tests of the first activity period were directed at demographics, aircraft attitudes, noise sensitivity, environmental sensitivity, (see Appendix D), perception preferences (Myers-Briggs Type Indicator, ref. 9), and self-concept information (Adjective Checklist, ref. 10). The tests of the second

activity period were directed at information about the individual's anxiety level (State-Trait Anxiety Inventory, ref. 11) and perceptual functions (Group Embedded Figures Test, ref. 12).

RESULTS AND DISCUSSION

This section provides results and discussions related to the five subobjectives listed in the objectives section. The implication of these results for the aircraft noise adaptation model are briefly discussed.

Overall Aircraft Noise Effects

In order to provide an overall summary of the effects of various aircraft noises (first objective) on annoyance, an analysis of variance was computed. The analysis of variance (7 x 2 x 4) consisted of factorial combinations of the seven airplane types for two operations and four noise levels with repeated measures on all dimensions. Table III provides a summary of the analyses that were computed separately for the two groups of subjects. The separate analyses were computed because there were several factors (such as typical amount of aircraft noise impact, hearing ability, etc.) that varied between the two subject groups in addition to general location of residence. The results of Table III indicate all of the main effects and all but one of their interactions were significant for both groups of subjects. The annoyance responses associated with these analyses are displayed in figures 8 to 12. Appendix E provides additional subdivisions of this data. The relative importance of the various main effects should be considered prior to a discussion of the implications of the results. Through increased sensitivity of the design (e.g., within-subject design as well as a large number of degrees of freedom) certain relatively small

systematic differences between experimental conditions may be overemphasized if not considered relative to the total response variation.

In order to place the main effects (noise level, type of operation, and aircraft type) in perspective as to their relative importance, several multiple correlations were computed using the independent factors of noise level, aircraft type, and types of operation to predict the individual annoyance responses for both groups of subjects. Table IV provides a summary of these analyses and indicates:

1. The correlations between the annoyance ratings and individual or combined predictors were similar for the two groups of subjects.

2. The use of the A-weighting allowed a slightly better prediction of annoyance ratings than no-weighting. This was indicated by the higher multiple correlations for analyses based on noise level measured in L_A as compared to L_P. The predictive advantage of L_A over L_P was attributed to a more appropriate weighting of relative noise level rather than type of aircraft or operation. This was indicated by the fact that a small amount of explained variance was attributed to either type of aircraft or operation (for either L_A or L_P based analyses); whereas there was a greater amount of explained variance for the single predictor of noise level measured in L_A than for noise level measured in L_P.

3. Noise level alone was the single most important predictor of annoyance ratings; this was indicated by the fact that the single predictor of noise level (either L_A or L_P) accounted for a large amount of explained variance, the amount of which was almost equal to the case in which all the predictors were used in the multiple correlation analysis.

4. Information as to the type of aircraft or operation was of little or no value for an overall prediction of annoyance response as these factors combined accounted for 1 percent or less of the overall response variation.

There are a number of implications that can be derived from the data analyses of Table IV and figures 8 to 12. Of particular interest are the following results:

1. There was monotonic increase of annoyance responses with noise level (figure 8).

2. There was a small difference between the annoyance responses produced by different aircraft which depended upon whether the aircraft noise results from a takeoff or an approach operation (figure 9). It should be remembered that the response variance explained by the factors of aircraft type and operation were extremely small in comparison to that which resulted from variations of noise level.

3. The approach operations were usually evaluated as more annoying than takeoff operations (figures 10 and 11). The fact that the DC-8 Turbojet and Concorde aircraft noises represented exceptions partially explains why the factors of aircraft type and type of operation were not of particular value for prediction of overall annoyance.

4. The New York subject group systematically evaluated the aircraft noises as more annoying than the Virginia subject group (figure 12). These systematic differences of annoyance response between subject groups occurred across noise level, aircraft type, and type of operation (figures 8 through 11).

The last result is of particular importance, since these group differences would logically occur if the average aircraft noise adaptation level of one group was lower than that for the other group. In other words, the response difference between groups seemed to reflect the absence of a universal aircraft noise adaptation level. Consequently, this last result offers direct support to the hypothesis that aircraft noise adaptation level is a viable concept that warrants further investigation.

Aircraft Noise Adaptation Levels

This section addresses the aircraft noise adaptation level measurements obtained during the pre and postthreshold periods of testing. An aircraft noise adaptation level was previously described as the lowest noise level at which the subject was annoyed 50 percent of the time. The exact procedure for computation of the level for each person is outlined in the method section. Once the aircraft noise adaptation level had been determined for each individual, the trends of these values were plotted for groups of subjects as displayed in figures 13 and 14. Figure 13 indicates the cumulative percent of each subject group that achieved their aircraft noise adaptation level (mean of pre and postthreshold measurements) for a given noise level. For example, the figure shows that 40 percent of the New York subjects had achieved their adaptation level by 73 dB whereas 40 percent of the Virginia subjects did not achieve their adaptation level until 79 dB. Figure 14 represents a division of the data of figure 13 into adaptation levels for pre and postthreshold testing as a function of noise level. These figures indicate that adaptation levels varied as a function of:

1. Different populations; the New York subjects displayed lower aircraft noise adaptation levels (greater sensitivity to noise) than Virginia subjects.

2. Subjects within a population; there was a variability of adaptation levels within each subject population.

3. Testing period; there was a decrease of measured adaptation level for a subject from prethreshold to postthreshold testing.

Psychophysical Relationships

The objective of this section is to combine the results of the two previous sections within the framework of the "Aircraft Noise Adaptation Model." Specifically, this involves determining if the accuracy in prediction of annoyance responses to aircraft noise is improved through

considering the aircraft noise relative to an individual's measured adaptation level. This problem of prediction actually involves optimization of prediction based upon selection of the most appropriate alternative from three interrelated factors:

1. The rating scale for specification of the physical aspects of the aircraft noise.

2. The mathematical formulation of the rating scale to subjective responses.

3. The mathematical computations necessary for inclusion of an individual's aircraft noise adaptation level (equation 1). Each of these factors is discussed independently prior to a review of the results of the present investigation.

Aircraft noise rating. - A variety of noise rating scales could be used for specification of aircraft noise (ref. 3). Although a large number of these ratings were initially considered in the present investigation, the discussion of results is restricted to the scales of L_{PNE}, L_A, L_C, L_{D1}, and L_{D3}. Alternative rating scales were eliminated due to their high correlation with one or more of the ratings incorporated in the study, or due to the low correlation between the rating scale and the subjective annoyance evaluations.

Mathematical relationship: psychophysical functions. - There are four potential psychophysical formulations that have usually been selected to describe the relationship of subjective evaluations to a physical measure of aircraft noise. These psychophysical relationships include:

1. Linear $AR = a + bx$
2. Exponential $AR = a10^{bx}$

3. Logarithmic $AR = a + b \log x$

4. Power $AR = ax^b$

where x is a mathematical expression (see column headings of Table V) of the test stimulus and measured aircraft adaptation levels in which the values of TS and AA are expressed as a pressure ratio (P/P_{ref}), and a and b are coefficients determined from the appropriate least-square fitting techniques.

Mathematical relationship: aircraft noise and measured adaptation. - There could potentially be a large number of mathematical relationships of the aircraft noise (TS) to an individual's measured aircraft noise adaptation level (AA). Some of the alternatives investigated in previous psychophysical work were used in the present series of analyses and are listed as column headings in Table V. The condition of TS alone (column 1) represents the case in which the measured aircraft noise adaptation level was considered to have no effect (i.e., AA = 1).

Prediction of Annoyance

Correlation coefficients (and consequently explained variance) were used to determine which unique combination of the above three factors optimized prediction of annoyance responses. Table V gives the correlation coefficients that resulted from these factorial combinations. It should be mentioned that these correlations were based on individual response data of all subjects, 80 Virginia and 29 New York City subjects, rather than means of response data. Consequently, the correlations reflect the actual percent of explained variance rather than inappropriately inflated estimates.

There are several important results determined from Table V which are of particular importance for development of the aircraft noise adaptation

model. These results and their implications include:

1. An overview of the results indicated there was a very large variation in the prediction accuracy of annoyance responses that results from the various combinations of physical rating, mathematical relationship, and psychophysical function. This variation is displayed by the fact that correlations ranged from 0.2845 (8 percent explained variance) to 0.8031 (65 percent explained variance).

2. Variance in prediction accuracy seemed least attributable to the use of different physical measures, more to use of different psychophysical functions, and most to use of various mathematical relationships.

3. The optimal prediction of annoyance responses resulted from the use of the physical noise rating of L_A, in conjunction with the mathematical relationship of (TS - AA) + TS and a logarithmic psychophysical function (correlation of 0.8031).

4. There was a minimum of 7 percent increase in explained variance (or more depending on reference point) attributable to the inclusion of an individual's aircraft noise adaptation level in the predictive equation of annoyance. This amount of explained variance occurred for the optimal prediction case, L_A, and logarithmic psychophysical function; between mathematical relationships 1 ($r = 0.7617$, explained variance = 58 percent) and 12 ($r = 0.8013$, explained variance = 65 percent).

The prediction of annoyance to aircraft noise was improved through incorporating a person's aircraft adaptation level in the prediction equation. A question at this time is what is the overall effect of different aircraft noise adaptation levels, or what effect does degree of noise sensitivity have on annoyance responses. Figure 15 displays the stimulus level increase

required for constant annoyance rating as a function of aircraft noise adaptation level. The graph can be understood through considering the two extremes: A person with a low aircraft noise adaptation level of 65 dB had a high noise sensitivity and required a 0 dB stimulus increase for a certain judged annoyance response. On the other hand, a person with a high aircraft adaptation level of 95 dB had a low noise sensitivity and required a 15 dB stimulus increase for a similar annoyance response. If a specific stimulus was evaluated on the subjective rating scale as 2 by a person with a low adaptation level, that same stimulus had to be increased by 15 dB in noise level to receive an equal subjective evaluation by a person with a high adaptation level

The implications of this figure are:

1. Aircraft annoyance varied considerably as a function of a person's aircraft noise adaptation level. Alternatively stated, constant annoyance responses resulted in aircraft noises separated by as much as 15 dB in level, depending on the noise sensitivity of the people who participated in the study.

2. The development of noise criteria for airport communities needs to account for the noise sensitivity of community residents.

Population Differences

An important question for future research and for development of the aircraft noise adaptation model is whether or not differences of aircraft noise adaptation level, as shown in figures 13 and 14, account for population differences reflected in the results shown in figures 8 to 12. In order to address this question, an assumption would be needed that is not fully understood from data of the present study. The group of subjects from

New York, on the average, displayed lower aircraft noise adaptation levels than the subjects from Virginia. The assumption would be needed that the aircraft noise adaptation levels of the two subject groups are merely extreme cases of a continuous distribution (of aircraft noise adaptation levels) rather than cases of uniquely different population. Due to the fact that these groups also differed in terms of location of residence, degree of typical aircraft noise impact, degree of typical street noise impact, hearing capacity, and attitudes, it is not clear whether or not the assumption would be clearly justified. Therefore, the analyses described to account for population differences need to be considered tentative pending collection of more comprehensive data regarding the distribution of aircraft noise adaptation levels.

Figure 16 displays the actual annoyance response of New York and Virginia subjects (data of figure 8), as well as adjusted responses for Virginia subjects as a function of noise level. The graph of adjusted Virginia subject responses is based on figure 15. The Virginia subjects displayed an average aircraft noise adaptation level of 7 dB higher than the New York subjects. For the task of adjusting responses of Virginia subjects to responses of New York subjects, the noises for Virginia subjects needed to be decreased 3.5 dB for purposes of comparison (from figure 15, an increase of 7 dB in aircraft noise adaptation level equates to stimulus level increase of 3.5 dB). Based on these assumptions, the difference between populations is cut in half, but certainly not eliminated. The implication is that the current version of the model accounts for some of the response variation; in this case between populations. However, due to the problems associated with distribution of aircraft noise adaptation levels, further work is needed in this area in order to derive final conclusions.

Predictors of Aircraft Noise Adaptation Level

This section is directed at an initial description of the psychological factors that explain (are correlated with) an individual's aircraft noise adaptation level which is the fifth objective listed in the objective section. Due to the restricted sample of subjects in the present investigation, and the large number of subjects that are usually needed in order to derive stable implications in personality-attitude type research, the following result should be treated as tentative.

Table VI provides the results of a stepwise multiple correlation analysis for prediction of aircraft noise adaptation levels based on the various psychological indices collected from each participant in the study. An exact definition of the psychological indices should be obtained from references 7 to 10 due to their technical and restricted meaning. In addition to the multiple correlation information, the column located at the extreme right-hand side of the table contains simple correlation coefficients between successive indices and aircraft noise adaptation levels. The results of the table indicate that attitude-personality indices allowed prediction of an individual's aircraft noise adaptation level, but there was no single psychological index that emerges as the sole predictor of an individual's aircraft adaptation level. The use of the first 16 predictors (based on a criterion that each predictor needed to account for 1 percent of the variance for inclusion in final prediction) resulted in a multiple correlation of 0.69 (explained variance = 48 percent), and that the factors of attitude toward noise, education level, and income level appeared to be important determiners of an individual's aircraft noise adaptation level. Future studies based on more extensive data will allow a more accurate evaluation of the adequacy of these results.

Composite Annoyance Prediction

An earlier section addressed the combination of factors (noise rating scale, mathematical relationship between aircraft noise and aircraft adaptation, and psychophysical function) that optimized prediction of annoyance responses. A major question at this time is whether or not the various attitude and personality scores obtained during the investigation can improve the predictive accuracy beyond that established earlier. Since the aircraft noise adaptation level of each person has been considered in these earlier analyses, the present analysis was directed at the explanation of response variance attributable to attitude-personality factors that has not been adequately accounted for through aircraft noise adaptation levels. Table VII provides the results of a stepwise multiple regression for prediction of annoyance responses based on both information previously derived for prediction optimization as well as the use of all the attitude-personality indices as separate predictors. The major result of the analyses displayed in Table VII was that an additional 3 percent (0.6810 - 0.6450) of the response variability (beyond the 7 percent of variability explained through the use of aircraft noise adaptation levels) was accounted for through the use of attitude-personality factors. Therefore, a minimum of 10 percent of the annoyance response variability was explained through the use of attitude-personality related factors. If the 3 percent of explained variance is obtained in a future study, the procedure for measuring aircraft noise adaption level may need extension or slight revision.

CONCLUSIONS

A series of studies is being conducted at Langley Research Center for the development of an aircraft noise adaptation model which can account for

much of the variability in the responses of subjects participating in human response to noise experiments. A sizeable portion of unexplained variability of annoyance responses to aircraft noise was accounted for through the concept of aircraft noise adaptation level and various attitude-personality indices. Specific conclusions from the investigation that related to the problem of response variability, the aircraft noise adaptation model, or its refinement include:

1. The annoyance response of different people (and groups of people) were documented and determined to exhibit considerable variability. The response variability was particularly evident between subject groups across noise levels, type of aircraft, and type of operation.

2. The noise level of an aircraft is the single most important factor for prediction of annoyance responses to aircraft noise. The type of aircraft or type of aircraft operation are of little or no value for the prediction of annoyance.

3. Aircraft noise adaptation levels were measurable and varied within and between populations, as well as from the beginning to the end of the experimental study. Group differences of aircraft noise adaptation levels varied in a fashion parallel to group differences of annoyance response.

4. Combination of information of the aircraft noise level with an individual's aircraft noise adaptation level increased the amount of explained variance of annoyance responses by 7 percent as compared to the situation where aircraft noise adaptation level was not considered. The optimal prediction of annoyance responses resulted from the use of the physical noise measure of L_A, the mathematical relationship between aircraft noise (TS) and aircraft noise adaptation level (AA) of (TS - AA) + TS, and a logarithmic psychophysical function.

5. Variation in the predictive accuracy of annoyance responses was least attributable to the use of different physical noise measures, more to the use of different psychophysical functions, and most to the use of different mathematical relationships between aircraft noise and an individual's aircraft noise adaptation level.

6. The annoyance responses of aircraft noise clearly varied as a function of a person's aircraft noise adaptation level; for example, two individuals gave equal annoyance responses for aircraft noises separated in A-level by 15 dB.

7. As an extension of the 7 percent of response variability explained in conclusion 4 above, an additional 3 percent of response variability was explained through the use of various attitude-personality indices. Consequently, 10 percent of the variability in annoyance reactions could be accounted for through the use of information about the participant.

8. The concept of aircraft adaptation accounted for approximately one-half of the annoyance response differences between groups of subjects. Therefore, information about the distribution of aircraft noise adaptation levels for various populations is needed for extension and refinement of the model in this aspect.

9. An individual's aircraft noise adaptation level was predictable with some accuracy from various attitude-personality indices.

10. There was no single psychological index that emerged as the sole predictor of an individual's aircraft noise adaptation level. Of the 16 different indices that provided a substantial prediction of an individual's aircraft noise adaptation level, the factors of attitude toward noise, education level, and income appeared to be the most important determiners (correlated with) of an individual's aircraft noise adaptation level.

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TABLE I. - SUBJECT DEMOGRAPHICS

Subjects			Residence: Virginia	Residence: New York Area
Number	Males		17	26
	Females		63	3
	Total		80	29
Age	Median		30	49
	Range		18 - 56	37 - 69
Audiogram*	Pre	Mean	5.24	20.04
		St. Dev.	2.83	12.43
	Post	Mean	4.98	20.07
		St. Dev.	2.74	12.03
	Total	Mean	5.11	20.05
		St. Dev.	2.78	12.12

*(dB level increases required to achieve hearing threshold)

TABLE II. - TEST SCHEDULE

Activity	Time Duration
Audiogram	Prior to Testing
Prethreshold Testing	15 minutes
Aircraft Overflights	30 minutes
Break	10 minutes
Aircraft Overflights	30 minutes
Attitude Tests	75 minutes
Break	15 minutes
Aircraft Modifications	30 minutes
Attitude Tests	25 minutes
Postthreshold Testing	15 minutes
Audiogram	After Testing

TABLE III. - SUMMARY OF ANALYSES OF VARIANCE OF ANNOYANCE RESPONSES TO AIRCRAFT OVERFLIGHTS FOR SUBJECTS FROM VIRGINIA AND NEW YORK

SOURCE	VIRGINIA				NEW YORK			
	Sum of Squares	Degrees of Freedom	Mean Square	F	Sum of Squares	Degrees of Freedom	Mean Square	F
P Airplane Type	101.7444	6	16.95739	13.4287*	124.6804	6	20.78006	15.5857*
Error (SxP)	598.5553	474	1.262775	-------	223.9903	168	1.333276	------
O Operation	209.8059	1	209.8059	100.5484*	31.86958	1	31.86958	13.2618*
Error (SxO)	164.8426	79	2.086615	-------	67.28733	28	2.403119	------
N Noise Level	19044.31	3	6348.104	914.4005*	7659.405	3	2553.135	466.2501*
Error (SxN)	1645.341	237	6.942367	-------	459.9749	84	5.475891	------
S Subjects	5218.661	79	66.05900	-------	1513.780	28	54.06358	------
PxO Interaction	645.4521	6	107.5754	85.5362*	235.9905	6	39.33175	27.5513*
Error (SxPxO)	596.1303	474	1.257659	------	239.8337	168	1.427581	------
PxN Interaction	98.67969	18	5.482205	4.7312*	63.83411	18	3.546339	3.2964*
Error (SxPxN)	1647.732	1422	1.158743	------	542.2060	504	1.075806	------
OxN Interaction	75.87036	3	25.29012	16.5030*	7.524414	3	2.508138	2.0929
Error (SxOxN)	363.1916	237	1.532454	------	100.6635	84	1.198375	------
PxOxN Interaction	139.8010	18	7.766724	6.5853*	135.9023	18	7.550123	7.2025*
Error (SxPxOxN)	1677.099	1422	1.179394	------	528.3218	504	1.048257	------

* $p < 0.05$

TABLE IV. - SUMMARY OF SIMPLE AND MULTIPLE CORRELATION COEFFICIENTS AND ASSOCIATED EXPLAINED VARIANCE (PERCENT) FOR PREDICTION OF INDIVIDUAL ANNOYANCE RESPONSES FOR BOTH SUBJECT GROUPS WHERE CORRELATION COEFFICIENTS ARE BASED ON EITHER L_A OR L_P UNITS OF MEASURE.

NOISE RATING SCALE	TYPE OF CORRELATION	PREDICTORS	SUBJECT GROUP: NEW YORK CITY		SUBJECT GROUP: VIRGINIA	
			CORRELATION	EXPLAINED VARIANCE	CORRELATION	EXPLAINED VARIANCE
L_A	Simple	Operations	0.052	(0.3)	0.081	(0.7)
		A/C Type	-0.070	(0.5)	-0.054	(0.3)
		Noise Level	0.793	(62.9)	0.756	(57.2)
	Multiple	All Three	0.800	(64.0)	0.765	(58.5)
L_P	Simple	Operations	0.052	(0.3)	0.081	(0.7)
		A/C Type	-0.070	(0.5)	-0.054	(0.3)
		Noise Level	0.770	(59.3)	0.726	(52.7)
	Multiple	All Three	0.787	(62.0)	0.747	(55.8)

TABLE V. - SUMMARY OF CORRELATION COEFFICIENTS* THAT RESULT FROM CORRELATION OF SUBJECTIVE RESPONSES WITH PHYSICAL NOISE MEASURES. THE CORRELATIONS RESULT FROM A PARAMETRIC COMBINATION OF FIVE PHYSICAL NOISE MEASURES, TWELVE MATHEMATICAL EXPRESSION OF AIRCRAFT NOISE AND AIRCRAFT ADAPTATION LEVEL, AND FOUR PSYCHOPHYSICAL FUNCTIONS.

PHYSICAL NOISE MEASURE	PSYCHOPHYSICAL FUNCTION	MATHEMATICAL EXPRESSION											
		1	2	3	4	5	6	7	8	9	10	11	12
		TS	$\frac{TS/AA}{TS+AA} \times 1000$	(AA-TS)+AA	$\frac{TS-AA}{TS \times AA} \times 1000$	(TS-AA)/TS	TS/AA	$\frac{TS}{TS+AA}$	TS-AA	$\frac{AA/TS}{TS+AA} \times 1000$	$\frac{(AA-TS) \times AA}{1000}$	$\frac{(TS-AA) \times TS}{1000}$	(TS-AA)+TS
L_{PNE}	Linear	.6955	.3218	.7248	.3811	.5735	.5748	.7153	.7121	.6209	.4347	.6043	.7043
	Exponential	.4674	.2845	.4971	.3421	.5447	.3779	.6277	.4836	.5921	.3120	.3792	.4758
	Logarithmic	.7577	.5610	.6980	.7555	.7677	.7733	.7739	.7875	.7816	.7924	.7959	.7992
	Power	.5784	.4671	.5660	6142	.6291	6070	.6214	.6229	.6262	.6318	.6098	.6221
L_A	Linear	.7103	.4434	.7339	.6697	.5583	.5836	.7890	.7535	.6494	.5688	.6498	.7414
	Exponential	.4831	.3566	.5353	5810	.5342	.3864	.6334	.5329	.5838	.4459	.4113	.5149
	Logarithmic	.7617	.5639	.6994	.7599	.7713	.7768	.7775	.7906	.7857	.7954	.7987	.8031
	Power	5803	.4687	.5664	.6167	.6311	.6087	.6232	.6243	.6284	.6332	.6108	.6240
L_C	Linear	6577	.3898	.7013	.5508	.5306	.5533	.7369	.6862	.5843	.4607	.5409	.6736
	Exponential	.4539	.3292	.5013	4852	.5100	3702	.6227	.4825	.5389	.3517	.3531	.4694
	Logarithmic	.7609	.5541	.6880	.7578	.7698	.7721	.7743	.7862	.7915	.7917	.7924	.8029
	Power	.5725	.4583	.5539	6091	.6238	.6000	.6150	.6157	.6252	.6250	.6016	.6175
L_{D1}	Linear	.6999	.3958	.7435	5692	.5618	.5755	.7661	.7308	.6363	.5124	.5992	.7177
	Exponential	.4727	.3320	.5227	.4980	.5358	.3795	.6398	.5042	.5824	.3827	.3777	.4901
	Logarithmic	.7606	.5536	.6928	7554	.7695	.7723	.7743	.7876	.7899	.7937	.7945	.8024
	Power	5742	.4589	.5583	.6093	.6253	.6016	.6168	.6180	.6263	.6275	.6041	.6187
L_{D3}	Linear	.7153	.4455	7346	.6861	.5738	.5840	.8030	.7585	.6760	.5783	.5997	.7472
	Exponential	.4788	.3571	.5305	.5946	5467	.3822	.6404	.5298	.6077	.4478	.3682	.5117
	Logarithmic	.7371	.5158	.6391	.7255	.7377	.7380	.7409	.7521	.7751	.7583	.7582	.7809
	Power	.5462	.4270	.5145	5787	.5928	.5709	.5845	.5861	.6037	.5956	.5742	.5953

* Negative correlations have been expressed as positive for ease of reading

TABLE VI. - A SUMMARY OF A STEP-WISE MULTIPLE CORRELATION ANALYSIS IN WHICH THE PREDICTORS OF AN INDIVIDUAL'S AIRCRAFT ADAPTATION LEVEL INCLUDED THE VARIOUS ATTITUDE-PERSONALITY INDICIES

Step Number	Variable Removed (Pyschological Index)	Subjective Scale	Multiple Correlation	Explained Variance	Simple Correlation
1	Noise attitudes	(see appendix D)	0.3884	0.1509	-0.388
2	Education level	Demographics	0.4842	0.2345	-0.336
3	Income level	Demographics	0.5226	0.2731	-0.315
4	Counseling readiness	Adjective checklist	0.5503	0.3029	-0.169
5	Weight	Demographics	0.5754	0.3311	-0.216
6	Environmental sensitivity	(see appendix D)	0.5892	0.3472	-0.093
7	Exhibition	Adjective checklist	0.5976	0.3571	0.101
8	Post-audiogram	Audiogram	0.6070	0.3684	-0.267
9	Aggression	Adjective checklist	0.6161	0.3795	-0.102
10	Intraception	Adjective checklist	0.6344	0.4024	-0.147
11	Embedded figure #2	Group embedded figure	0.6472	0.4188	-0.060
12	Embedded figure #1	Group embedded figure	0.6638	0.4406	-0.194
13	Aircraft attitudes	(see appendix D)	0.6727	0.4526	0.282
14	Autonomy	Adjective checklist	0.6785	0.4603	-0.051
15	Judgment-perception	Myers-Briggs type Indicator	0.6857	0.4702	0.099
16	Trait anxiety	State-trait anxiety inventory	0.6911	0.4776	0.016
17	Pre-audiogram	Audiogram	0.6943	0.4821	-0.242
18	State anxiety	State-trait anxiety inventory	0.6977	0.4868	-0.168
19	Change	Adjective checklist	0.7015	0.4922	-0.232
20	Total adjectives marked	Adjective checklist	0.7034	0.4948	-0.045
21	Self Control	Adjective checklist	0.7057	0.4981	0.054

TABLE VI. - CONCLUDED.

Step Number	Variable Removed (Psychological Index)	Subjective Scale	Multiple Correlation	Explained Variance	Simple Correlation
22	Order	Adjective checklist	0.7077	0.5008	-0.141
23	Endurance	Adjective checklist	0.7114	0.5061	-0.057
24	Self confidence	Adjective checklist	0.7176	0.5149	-0.116
25	Achievement	Adjective checklist	0.7196	0.5178	-0.002
26	Nurturance	Adjective checklist	0.7214	0.5204	0.060
27	Personal adjustment	Adjective checklist	0.7238	0.5239	0.031
28	Favorable adjectives	Adjective checklist	0.7249	0.5255	0.101
29	Extraversion-Introversion	Myers-Briggs type inventory	0.7266	0.5280	0.002
30	Lability	Adjective checklist	0.7279	0.5298	-0.063
31	Heterosexuality	Adjective checklist	0.7288	0.5311	0.077
32	Abasement	Adjective checklist	0.7301	0.5331	-0.045
33	Thinking-feeling	Myers-Briggs type inventory	0.7308	0.5340	-0.035
34	Sex	Demographics	0.7311	0.5345	0.296
35	Age	Demographics	0.7313	0.5348	-0.247
36	Succorance	Adjective checklist	0.7314	0.5350	-0.031
37	Affiliation	Adjective checklist	0.7315	0.5351	0.135
38	Sensing-intuition	Myers-Briggs type inventory	0.7316	0.5352	-0.110
39	Unfavorable adjectives	Adjective checklist	0.7317	0.5353	0.060
40	Dominance	Adjective checklist	------	------	-----
41	Deference	Adjective checklist	------	------	-----
42	Mean audiogram	Audiogram	------	------	-----

TABLE VII. - A SUMMARY OF A MULTIPLE CORRELATION ANALYSIS IN WHICH THE PREDICTORS OF ANNOYANCE RESPONSE INCLUDED THE OPTIMAL PREDICTION FORMULA AS WELL AS VARIOUS ATTITUDE-PERSONALITY INDICES

Step Number	Variable Removed	Subjective Scale	Multiple Correlation	Explained Variance
1	Optimal prediction	Previous analyses	.8031	.6450
2	Unfavorable adjectives	Adjective checklist	.8102	.6564
3	Noise attitudes	(see appendix D)	.8167	.6670
4	Sex	Demographics	.8203	.6729
5	Age	Demographics	.8220	.6757
6	Population	Demographics	.8252	.6810

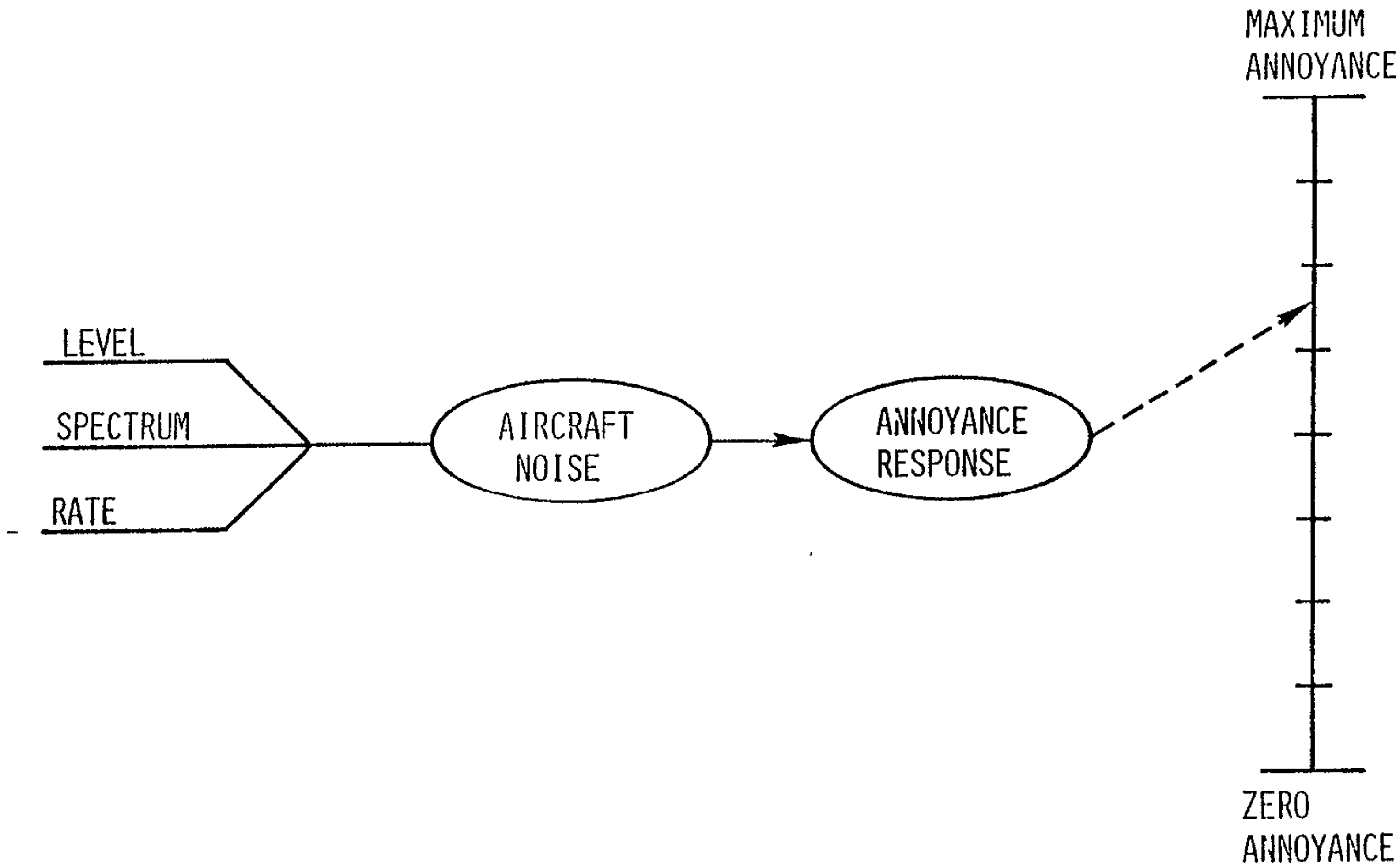


Figure 1.- Traditional aircraft noise study technique.

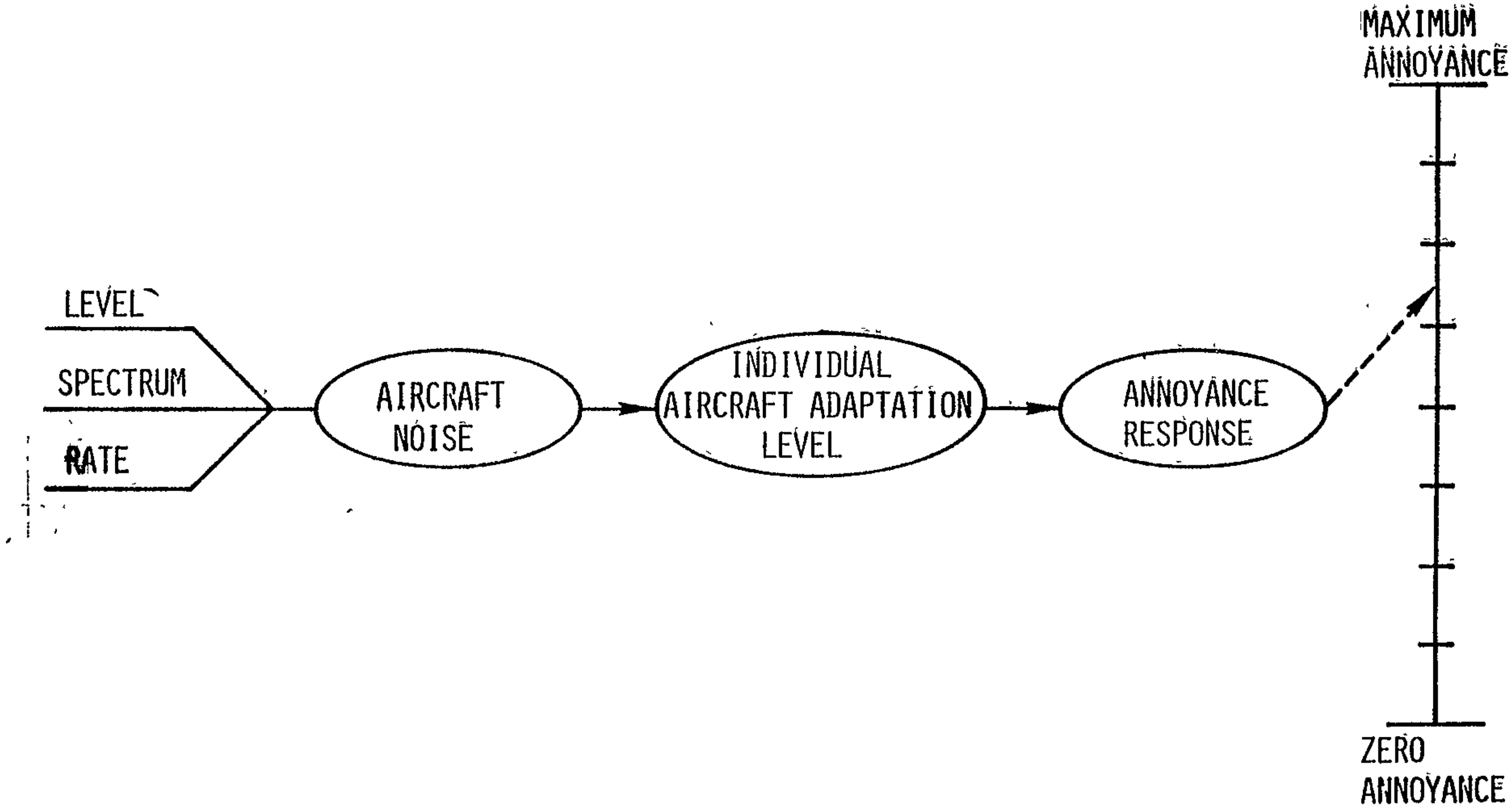


Figure 2.- Aircraft noise study technique incorporating aircraft adaptation model.

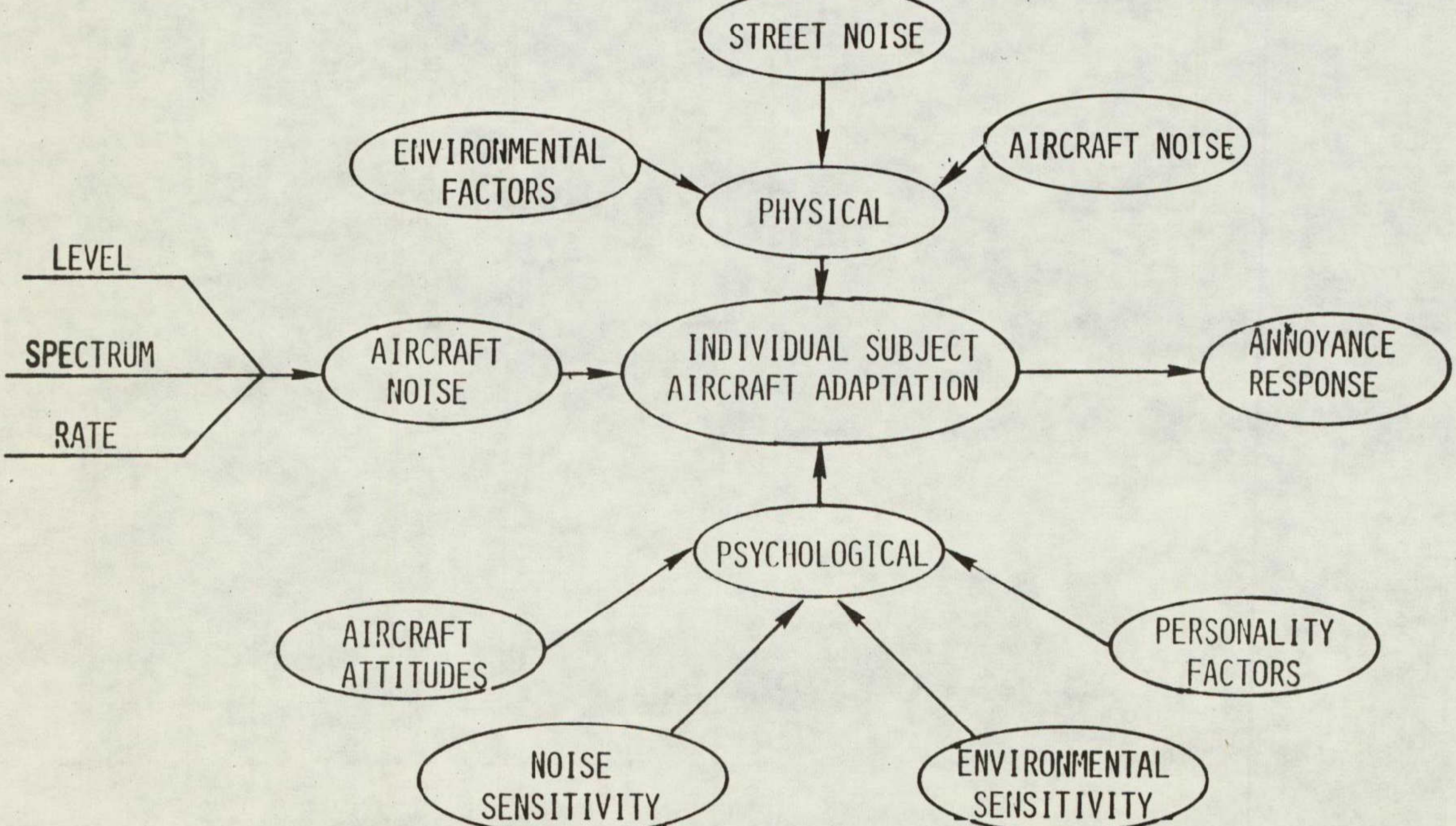


Figure 3.- Components of Aircraft Adaptation Model.

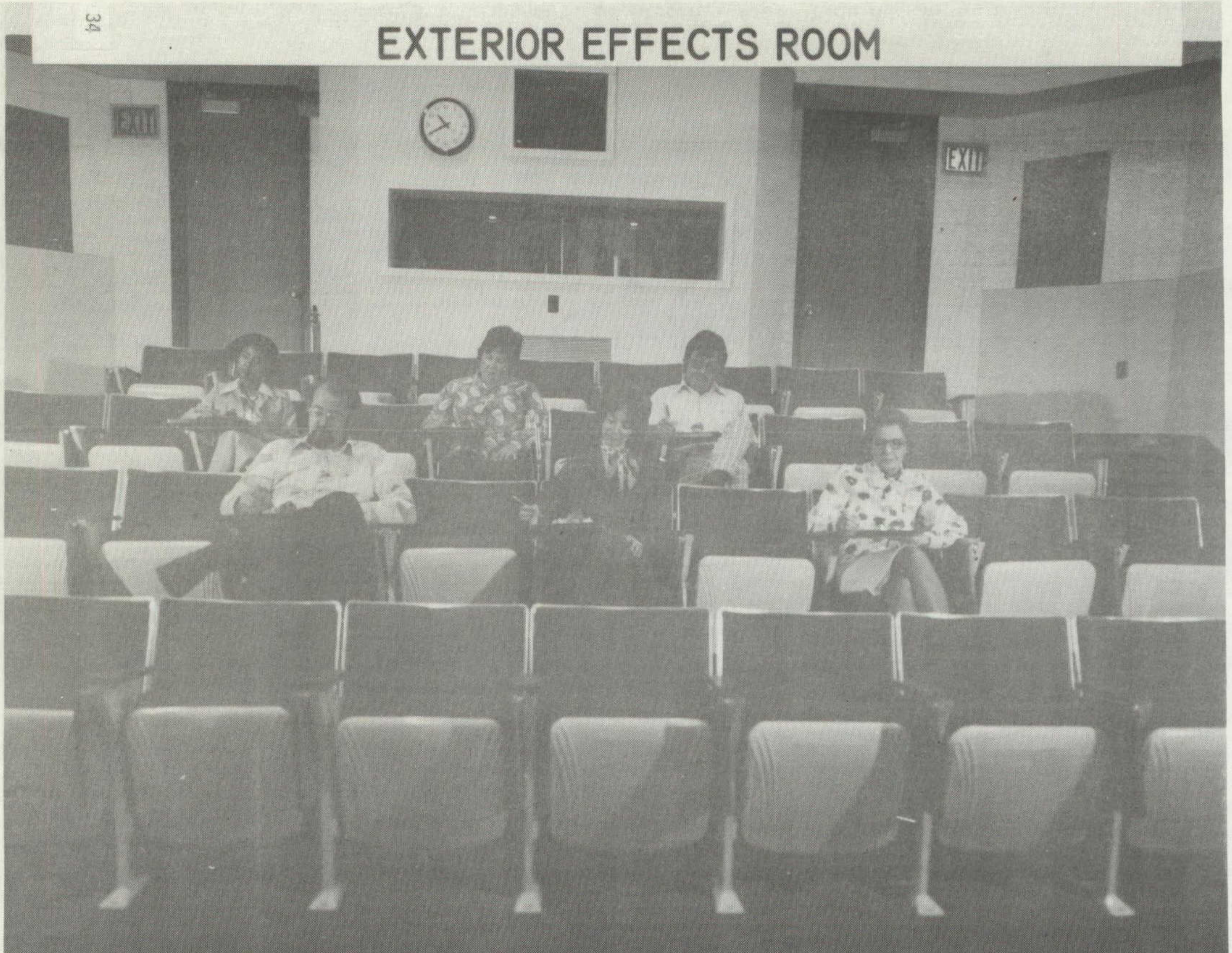


Figure 4.- Exterior Effects Room of Langley Research Center's Aircraft Noise Reduction Laboratory.

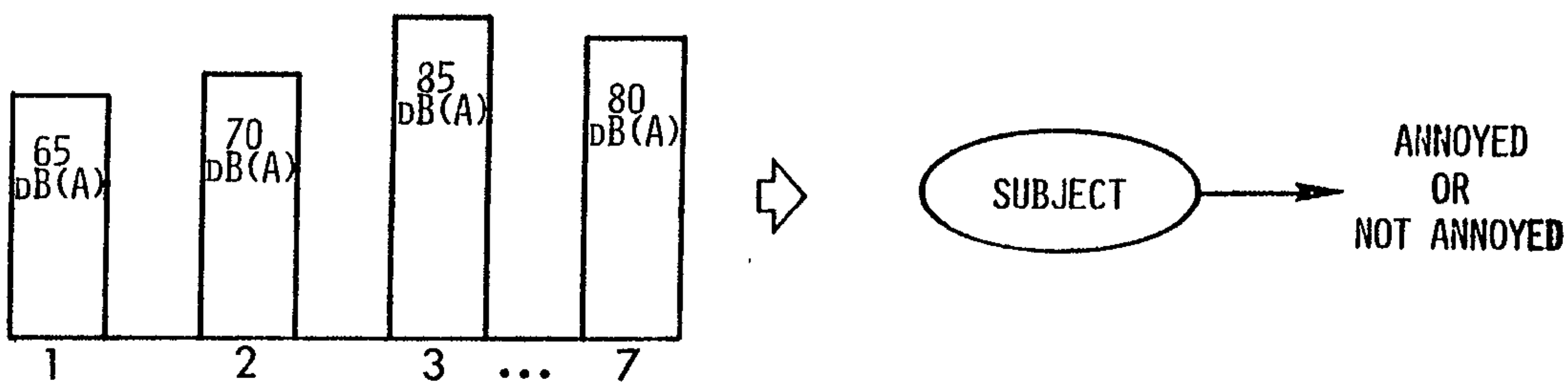


Figure 5.- Procedure for determining measured aircraft noise adaptation level.

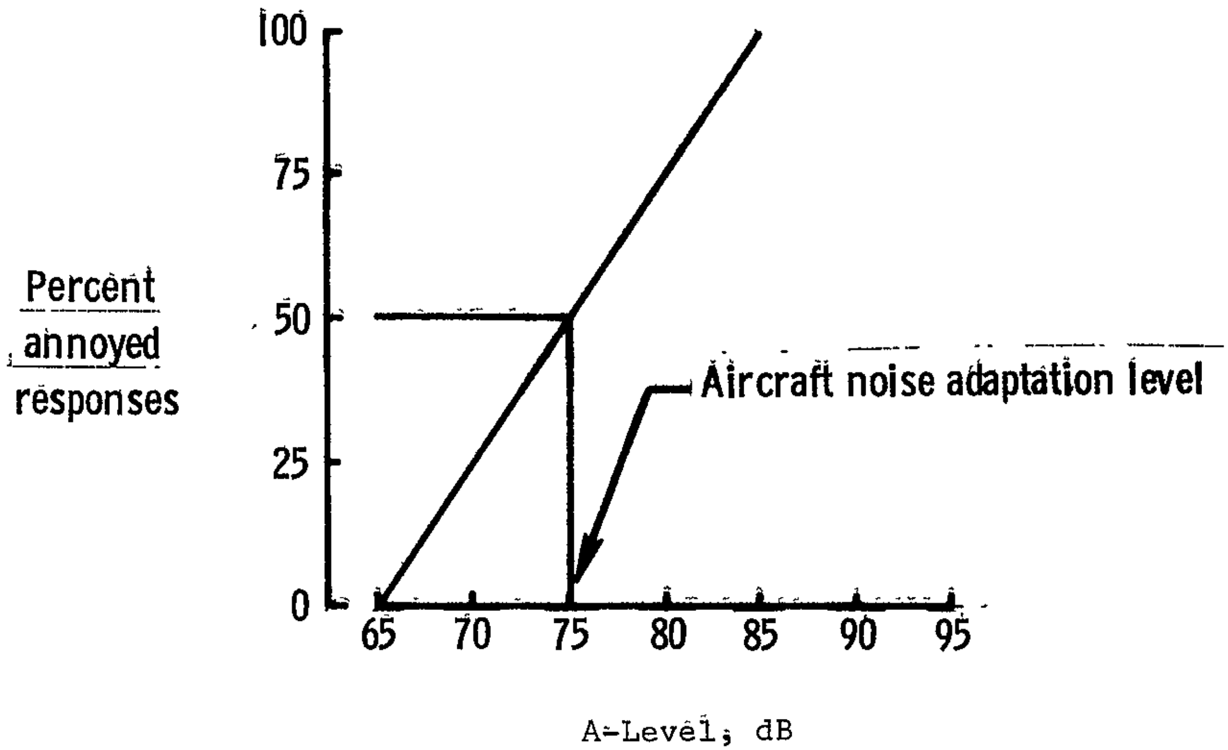


Figure 6.- Example of measured aircraft noise adaptation level for one subject.

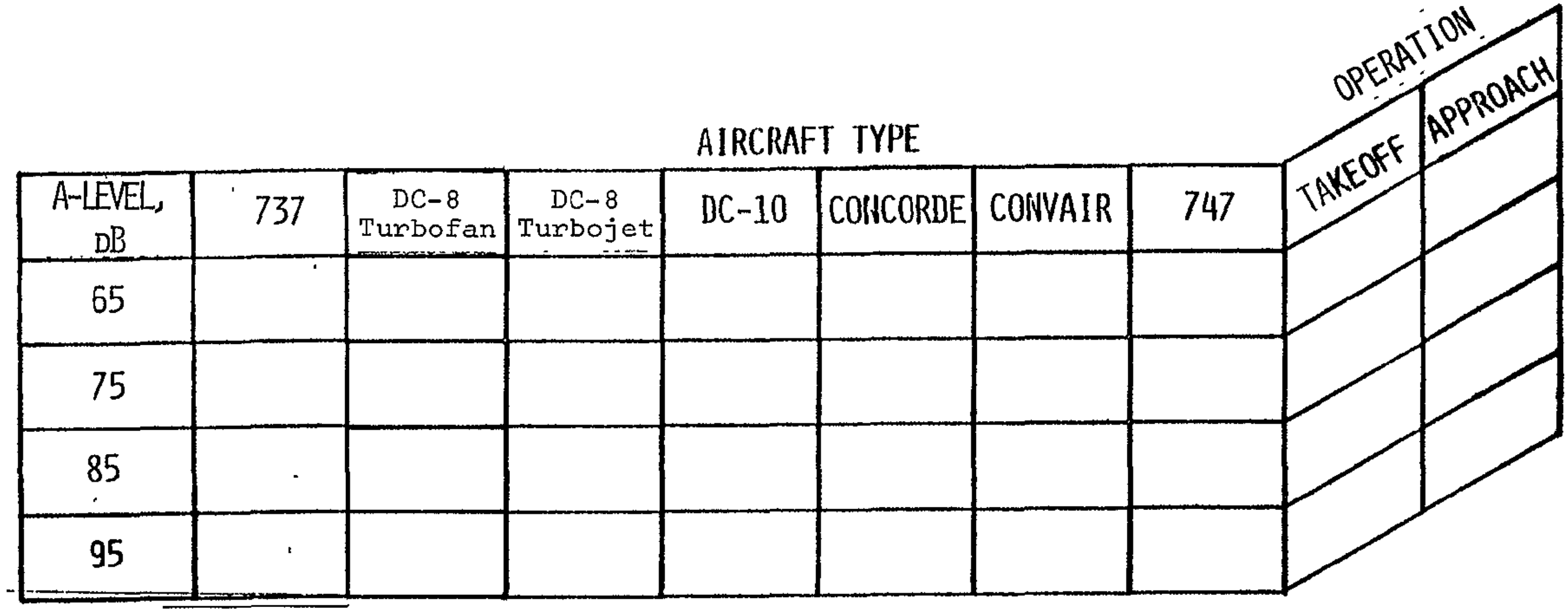


Figure 7. - Experimental design of aircraft adaptation model development study.

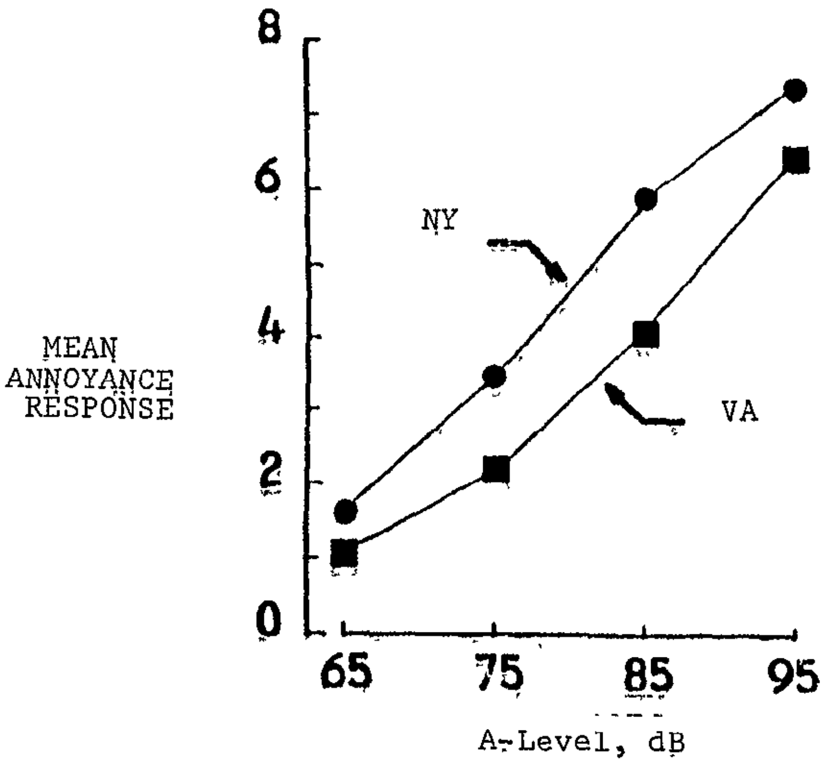


Figure 8.- Mean annoyance response for Virginia and New-York subject groups as a function of A-level. Annoyance responses are averaged across aircraft, operation, and within subject groups.

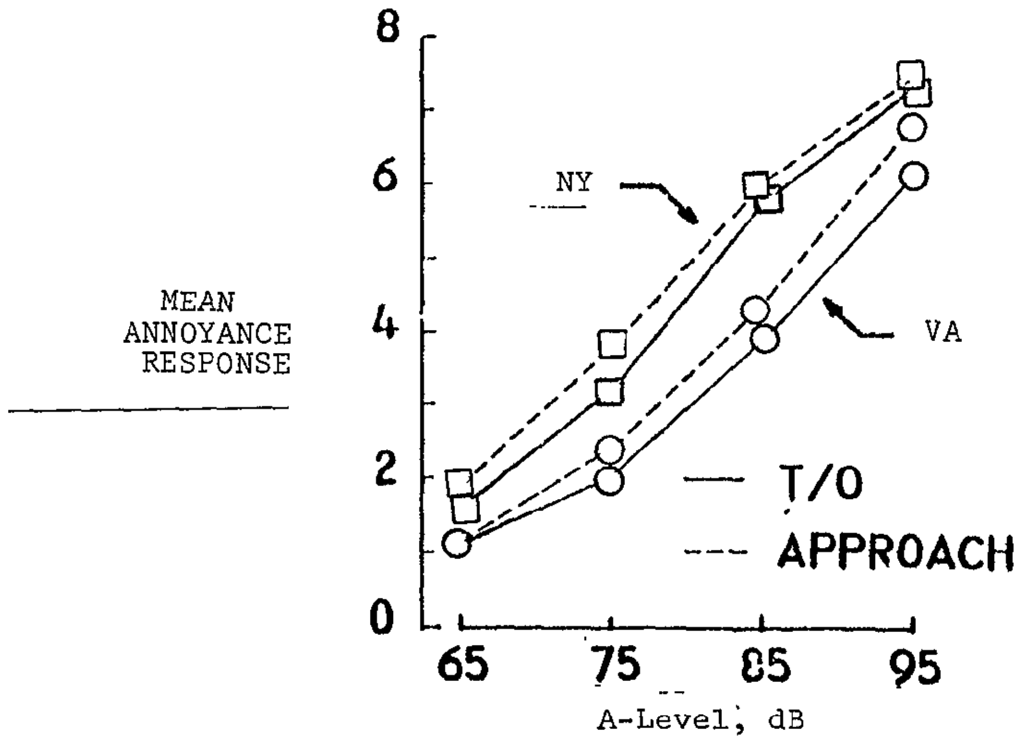


Figure 9.- Mean annoyance responses for Virginia and New York subject groups for takeoff and approach operations as a function of A-level. Annoyance responses are averaged across aircraft and within subject groups.

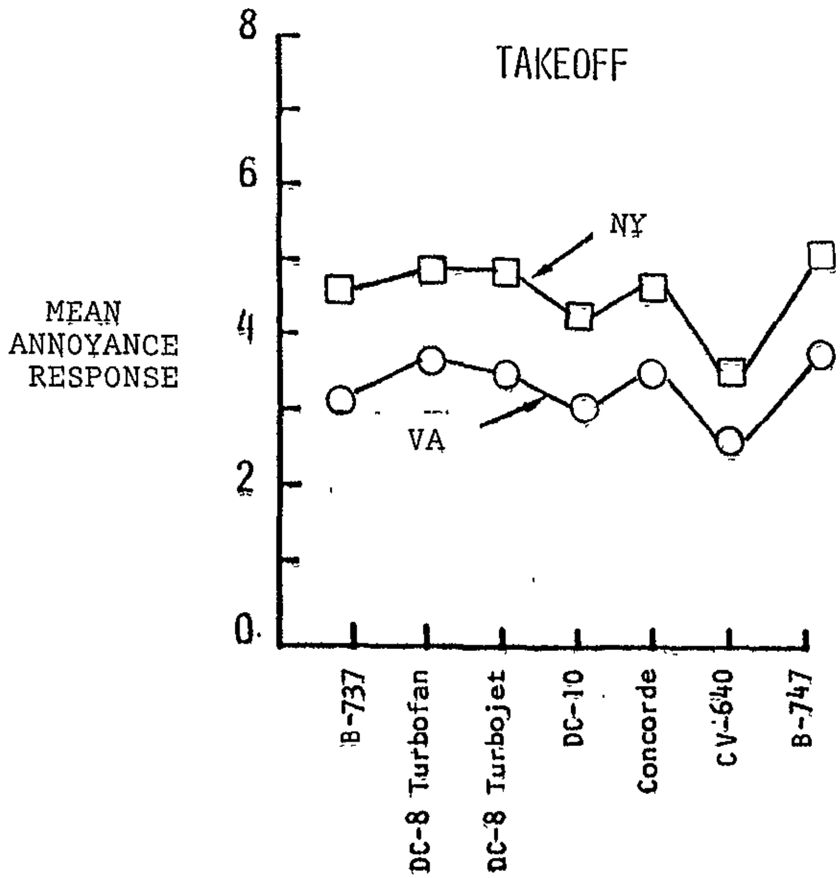


Figure 10.- Mean annoyance responses for Virginia and New York subject groups as a function of aircraft type for the takeoff operation. Annoyance responses are averaged across noise level within a subject group.

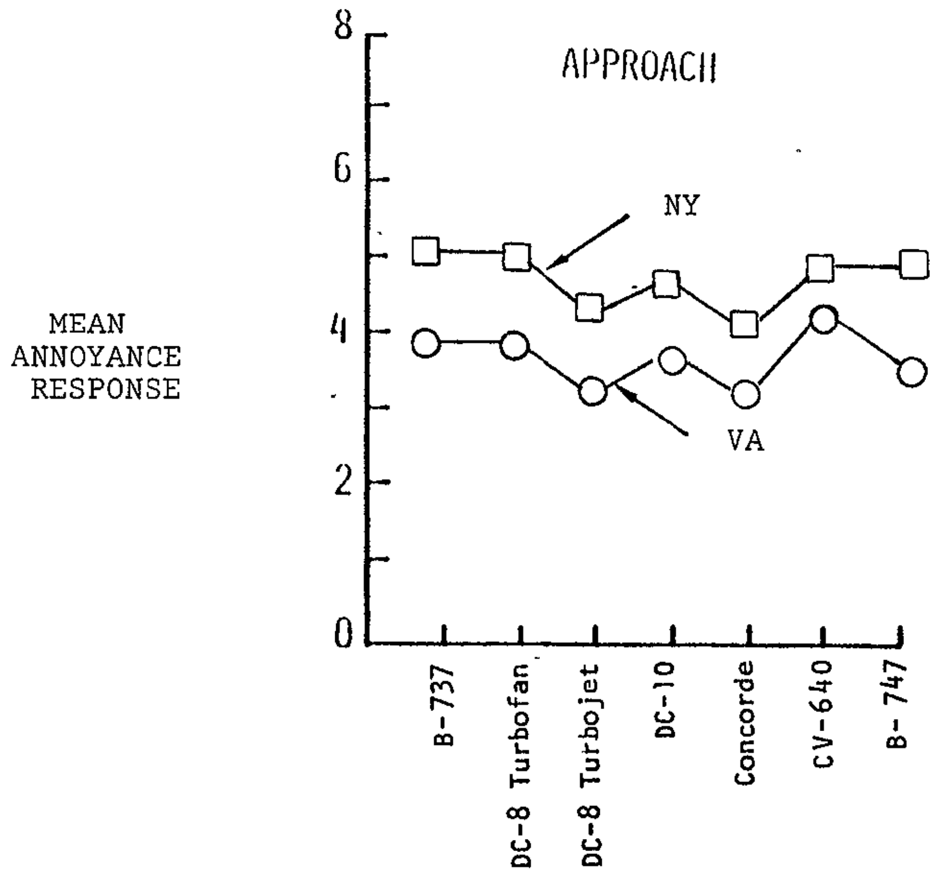


Figure 11.- Mean annoyance responses for Virginia and New York subject groups as a function of aircraft type for the approach operation. Annoyance responses are averaged across noise level within a subject group.

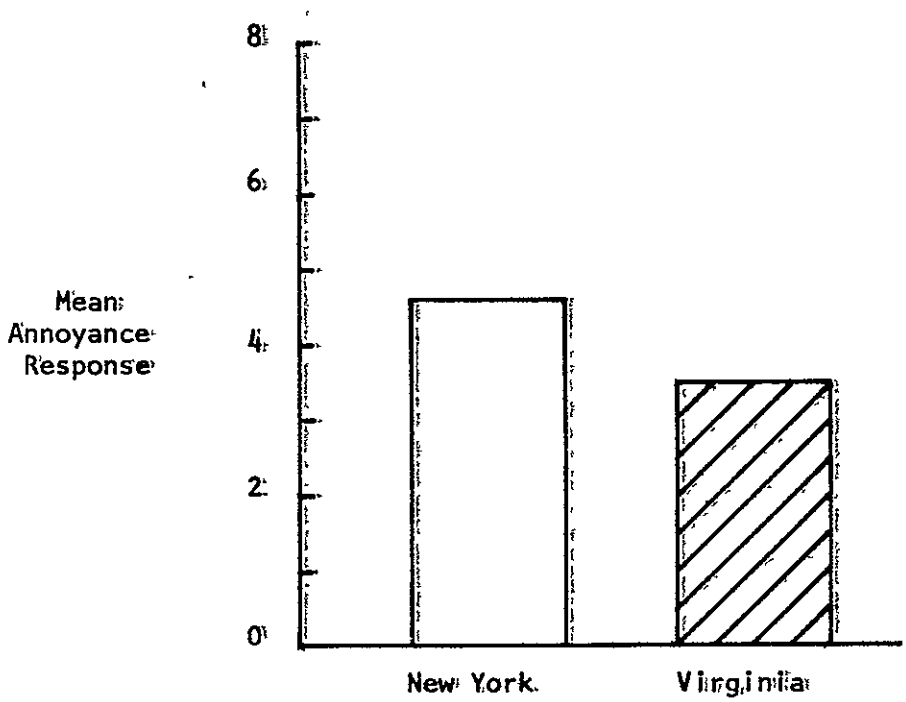


Figure 12.- Mean Annoyance Responses as a function of subject groups. The annoyance responses have been averaged across noise levels, aircraft, aircraft operation, and subjects within a group.

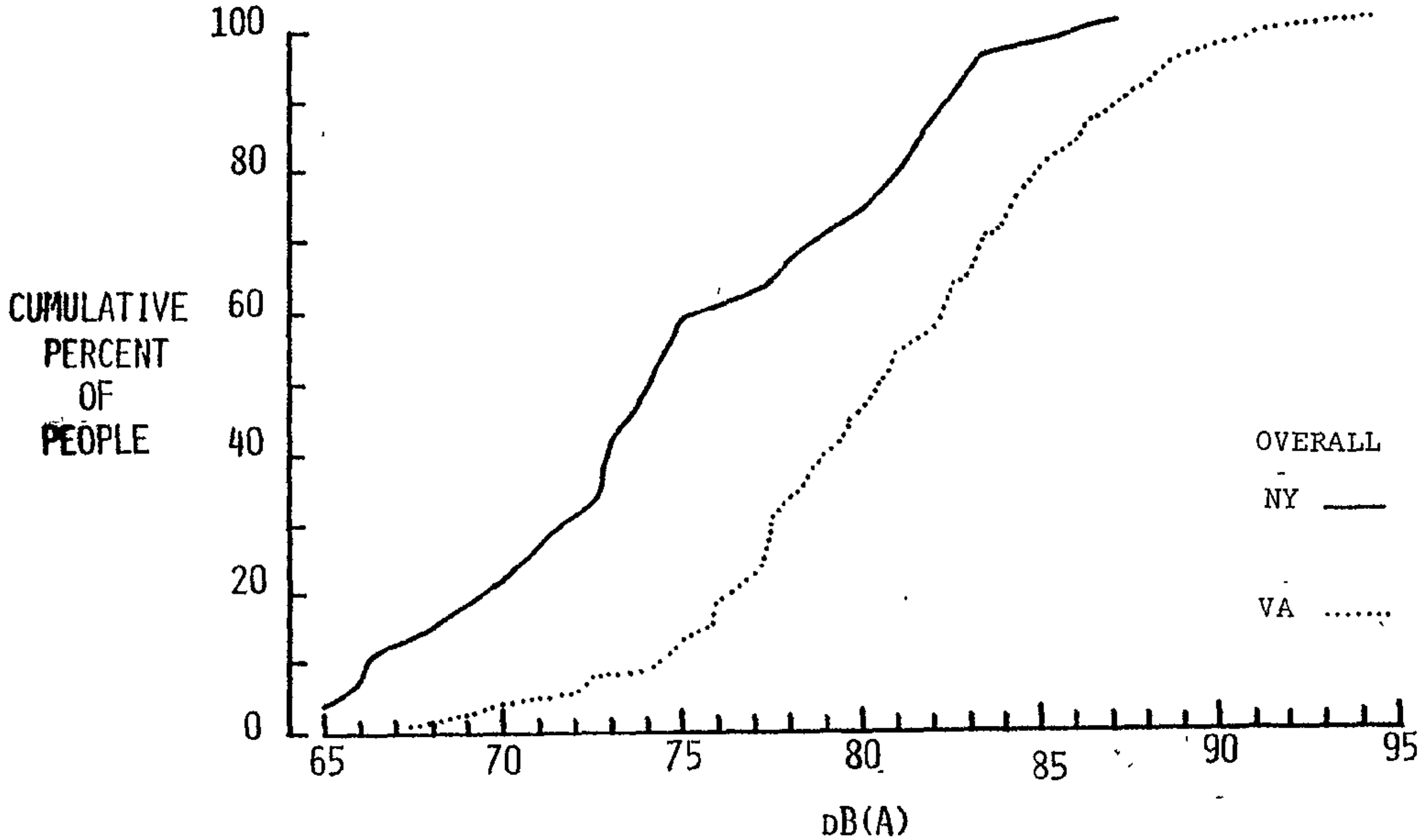


Figure 13.- Cummulative proportion of subjects that achieved aircraft adaptation levels for increases of A-level. Aircraft adaptation levels for computation of proportions are averaged for prethreshold and postthreshold testing.

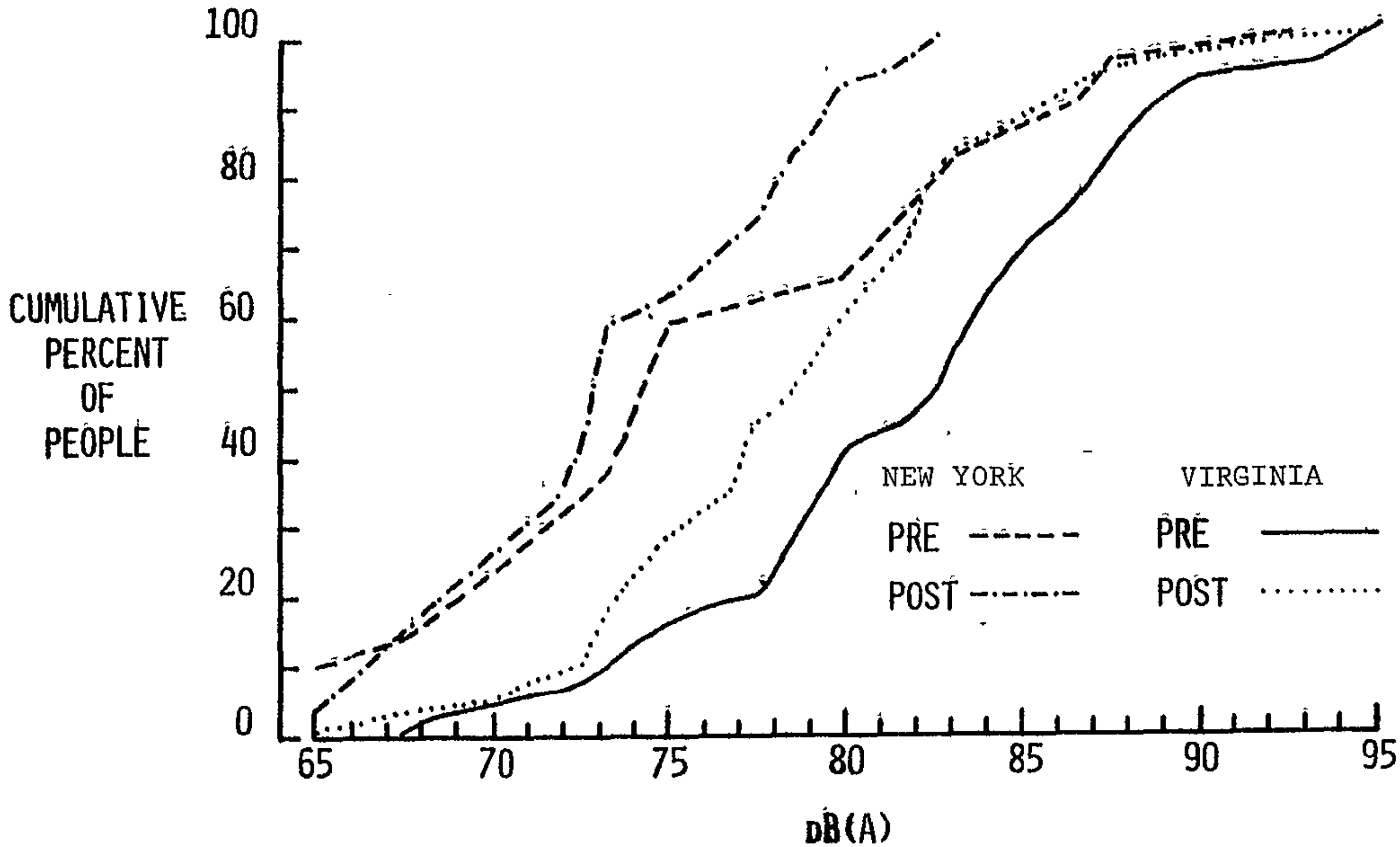


Figure 14.- Cummulative proportion of subjects for prethreshold and postthreshold testing that achieved aircraft adaptation levels for increases of A-level.

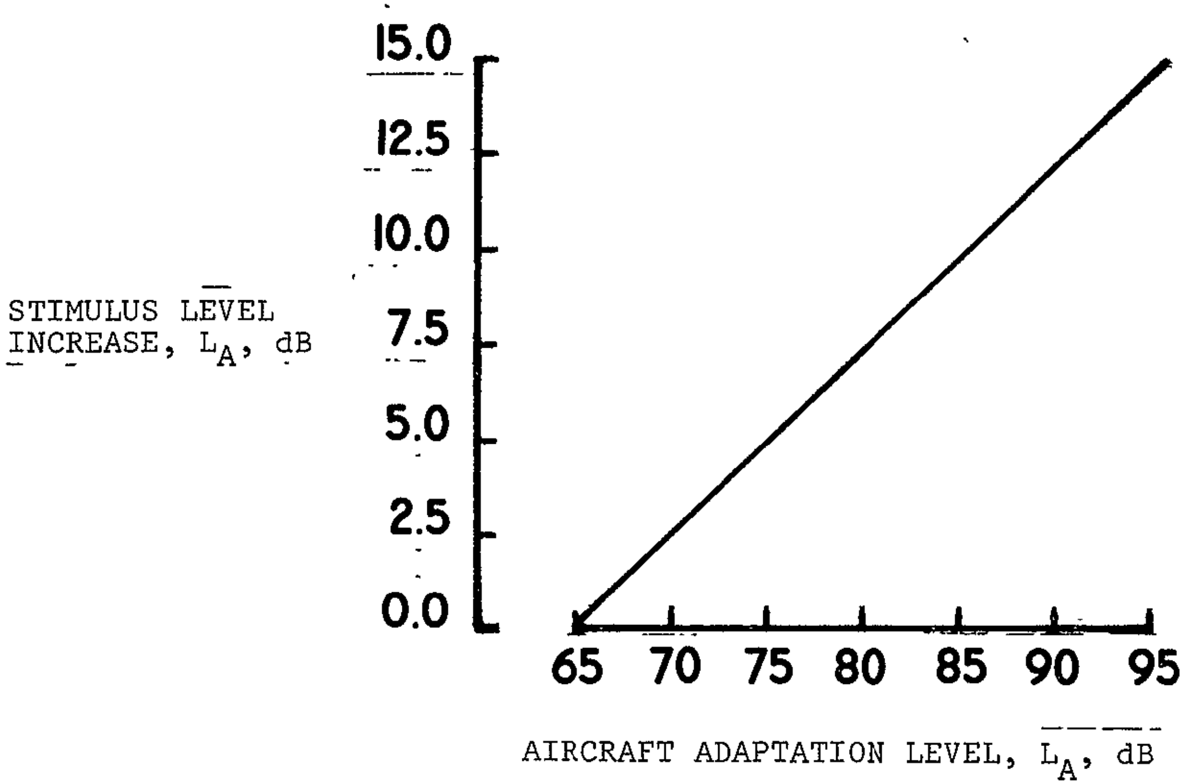


Figure 15.- Stimulus level increases required for constant annoyance as a function of an individual's aircraft adaptation level.

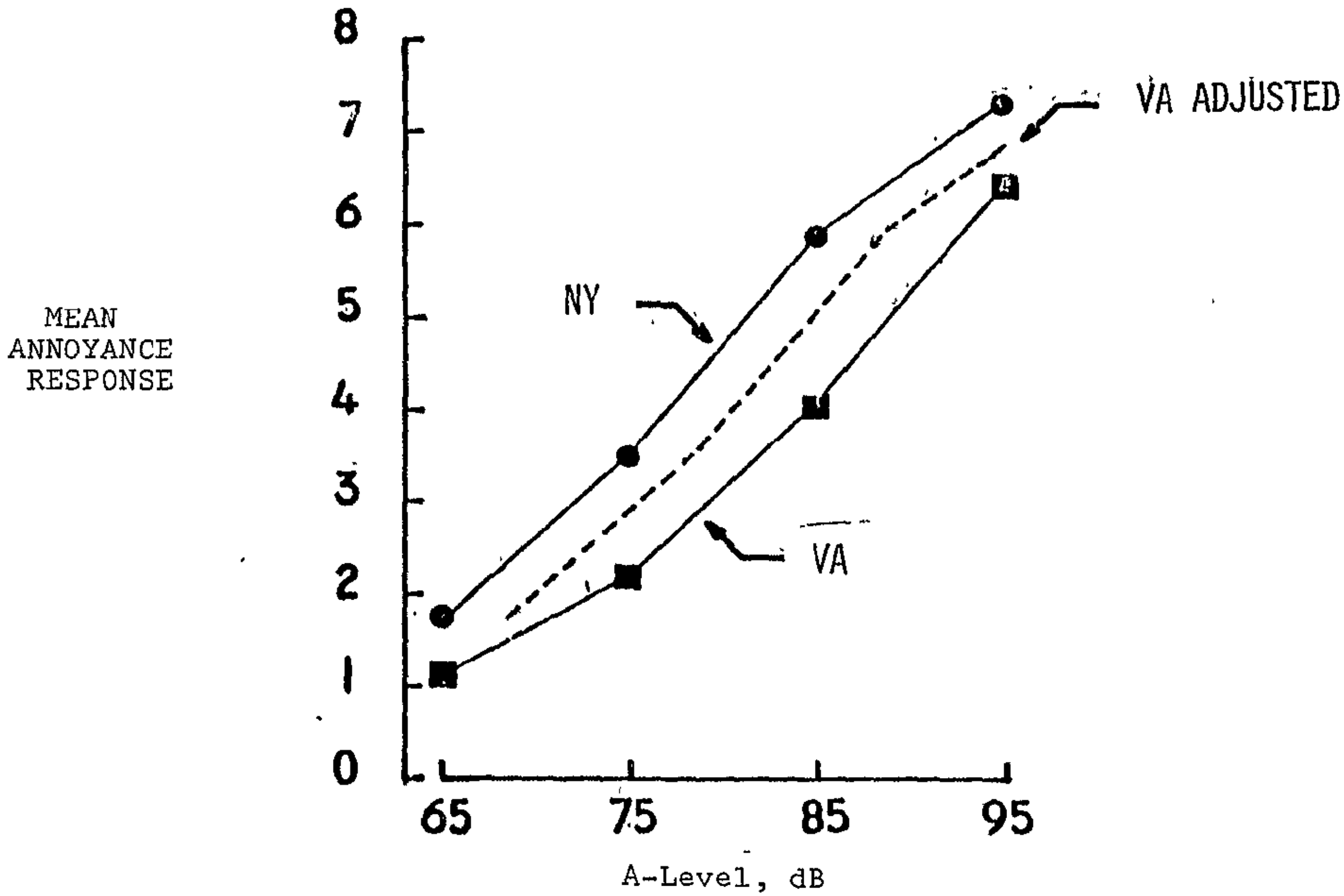


Figure 16.- Mean annoyance responses for subject groups from Virginia and New York as well as adjusted responses for the Virginia subject group (see text), as a function of noise level.

APPENDIX A

CONSENT FORMS

VOLUNTARY CONSENT FORM FOR SUBJECTS
FOR HUMAN RESPONSE TO AIRCRAFT NOISE AND VIBRATION

I understand the purpose of the research and the technique to be used, including my participation in the research, as explained to me by the Principal Investigator (or qualified designee).

I do voluntarily consent to participate as a subject in the human response to aircraft noise experiment to be conducted at NASA Langley Research Center on ____________________.
date

I understand that I may at any time withdraw from the experiment and that I am under no obligation to give reasons for withdrawal or to attend again for experimentation.

I undertake to obey the regulations of the laboratory and instructions of the Principal Investigator regarding safety, subject only to my right to withdraw declared above.

____
Signature of Subject

APPENDIX A

(cont.)

VOLUNTARY CONSENT FORM FOR RECORDING OF

SUBJECTS RESPONSE TO AIRCRAFT NOISE AND VIBRATION

I understand that AUDIO/VIDEO recordings are to be made of my response to the AIRCRAFT NOISE AND/OR VIBRATION experiment to be conducted at NASA Langley Research Center on _________________, and that these recordings are to be held in strictest confidence.

I have been informed of the purpose of such recordings and do voluntarily consent to their use.

I further understand that I may withdraw my approval of such recordings at any time before or during the actual recording.

____
Signature of Subject

APPENDIX B

INSTRUCTIONS FOR PRE- OR POST-THRESHOLD TESTING

INSTRUCTIONS: THRESHOLD TESTING

The task you will now be required to perform is to evaluate the annoyance of several noises. I will specify the experimental number and beginning of a noise with the digital display located in the front of the room. Each noise will last for approximately 15 seconds. Then when the number display disappears, indicating that the noise has stopped, you are to evaluate the annoyance of the noise. The evaluation you provide is to be either that the noise was annoying (A), or that the noise was not annoying (NA).

Are there any questions?

Remember:

1. Watch the numerical display in front of the room for indication of the number of the noise.
2. Evaluate each noise as either annoying (A) or not annoying (NA).
3. Record your evaluation

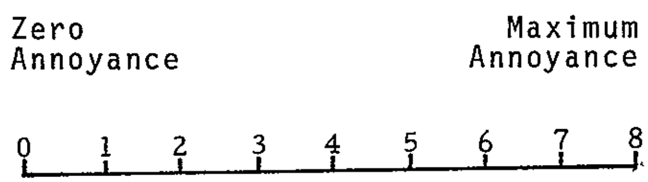
Are there any questions?

APPENDIX C

INSTRUCTIONS FOR AIRCRAFT NOISES

INSTRUCTIONS: AIRCRAFT OVERFLIGHTS

The task you will now be required to perform is to evaluate the degree of annoyance associated with various aircraft overflights. I will specify the flyover number and beginning of a noise with the digital display located in the front of the room. After the noise has stopped, you are to evaluate the annoyance of the aircraft noise. Evaluate the annoyance of each aircraft noise in terms of the following scale:



There will be several seconds between successive aircraft flyovers to allow you to make your evaluation.

Evaluation marks.- You should record your evaluation of the annoyance associated with each aircraft noise by placing a checkmark (e.g. √) upon the scale. Try to be careful in recording your evaluations because the point of the checkmark (√) will be used in interpretation of distance along the scale.

Scale interpretation.- The scale should be conceived of as representing the total range of annoyance you may associate with aircraft noise. In addition, the annoyance scale should be interpreted as if equal numerical distances represent equal amounts of annoyance. For example, the amount of annoyance between 1 and 2 is equal to the amount of annoyance between 5 and 6.

Consistency.- It is typical for participants in the study to "try and be consistent." Instead of trying to make evaluations consistent with previous aircraft flyover evaluations, try and evaluate each flyover without looking at previous evaluations. Please do not be concerned about whether your ratings agree with others in the room with you. Remember we want to know how different people feel about the aircraft flyovers. You may talk between the aircraft flyovers you are to rate, but please do not talk during them. It is also typical for participants to feel that they are not doing well at this task. It is usually true, however, that participants are doing better than they think they are, so don't be discouraged if you find the task difficult or monotonous at times.

Remember:

1. Watch the numerical display in front of the room for indication of the aircraft flyover number.
2. Evaluate the annoyance of each aircraft flyover.
3. Carefully record your evaluation mark.

Are there any questions?

APPENDIX D

DEMOGRAPHICS AND ATTITUDE TESTS

D E M O G R A P H I C S

1. Address: ____

____
city state zip

2. Subject number________________

3. Age____________ 4. Weight___________ 5. Sex________

6. Education: Circle last grade completed.

Did not finish grade school	01
Did not finish high school	02
High School graduate	03
College through	
freshman	04
sophomore	05
(two year college graduate, A.A., A.S.)	06
junior	07
College graduate	08
Some post graduate work	09
Master's Degree	10
Ph.D. or other doctorate degree	11
Professional degree (M.D., L.I.D. etc)	12
Other (Specify)	13

____

7. Economic Level: Circle the category which best estimates the total combined income of your household last year before taxes. Please include income from all sources, (i.e., wages, salaries, social security or retirement benefits, help from relatives, rent from property, etc.).

Under \$5,000	01
\$5,000 - \$9,999	02
\$10,000 - \$14,999	03
\$15,000 - \$19,999	04
\$20,000 - \$24,999	05
\$25,000 - \$29,999	06
\$30,000 or more	07

Subject No.____________

ATTITUDE SCALE

DIRECTIONS: This form measures your attitudes on a number of important issues. Each item is a statement of belief or attitude. At the right of each statement is a place for you to indicate your feeling. Please circle the symbols that best express your point of view. Please respond in terms of how you feel, not how you think others feel or what society wants you to feel. The symbols at the right of each item are as follows:

SD - Strongly Disagree
D - Disagree
? - Undecided
A - Agree
SA - Strongly Agree

Circle the symbol that expresses your point of view.
WORK QUICKLY AND PLEASE RESPOND TO EVERY ITEM.

* * * * * *

1.	I become upset more quickly when it's noisy.	SD	D	?	A	SA
2.	Aircraft noise prevention really is not worth the effort required.	SD	D	?	A	SA
3.	I believe that highway noise has gotten to be unbearable.	SD	D	?	A	SA
4.	Airplanes sometimes bother me with their noise.	SD	D	?	A	SA
5.	Airplane noise is not as big a problem as the noise made by the large trucks on the highway.	SD	D	?	A	SA
6.	The increase in noise levels in our environment is one of our most serious problems.	SD	D	?	A	SA
7.	I am very sensitive to air pollution.	SD	D	?	A	SA
8.	Now and then, aircraft noise gets on my nerves.	SD	D	?	A	SA
9.	Nothing is louder than a big airplane taking off.	SD	D	?	A	SA
10.	One of the biggest factors in determining where I will buy or rent my next residence will be the noise level within the community.	SD	D	?	A	SA
11.	The noise that airplanes make is a small price to pay for the convenience they provide.	SD	D	?	A	SA
12.	Small changes in room temperature interfere with my concentration.	SD	D	?	A	SA
13.	Aircraft noise bothers only those few people who live near the large airports.	SD	D	?	A	SA

SD - Strongly Disagree
D - Disagree
? - Undecided
A - Agree
SA - Strongly Agree

* * *

14.	Aircraft noise is no more bothersome than any other type of noise.	SD	D	?	A	SA
15.	Airports should be built in low population areas so that the noise of the planes annoy as few people as possible.	SD	D	?	A	SA
16.	I can't work when there's any kind of noise.	SD	D	?	A	SA
17.	Airplanes are one of the biggest sources of noise pollution.	SD	D	?	A	SA
18.	I rarely even notice low flying aircraft.	SD	D	?	A	SA
19.	Aircraft noise sometimes interferes with my T.V. watching.	SD	D	?	A	SA
20.	There should be strict federal restrictions on noise levels of aircraft.	SD	D	?	A	SA
21.	I cannot carry on an intelligent conversation if there is a lot of noise in the room.	SD	D	?	A	SA
22.	Changes in temperature have a telling effect on me physically.	SD	D	?	A	SA
23.	I am disturbed by the slightest change in a noise level I'm used to.	SD	D	?	A	SA
24.	While aircraft noise causes me some irritability, I can quickly adapt to it.	SD	D	?	A	SA
25.	Small changes in my normal environment are very disturbing to me.	SD	D	?	A	SA
26.	A great many times sounds interfere with my train of thought.	SD	D	?	A	SA
27.	While very loud aircraft noise is obnoxious, lower levels are easily tolerated.	SD	D	?	A	SA
28.	Noise that happens for a useful purpose bothers me less than needless noise.	SD	D	?	A	SA
29.	While low flying aircraft are certainly loud, they pass so quickly that the disturbance is minor.	SD	D	?	A	SA
30.	The convenience provided by modern aircraft outweighs the noise they contribute to the environment.	SD	D	?	A	SA

SD - Strongly Disagree
D - Disagree
? - Undecided
A - Agree
SA - Strongly Agree

* * *

31. While aircraft noise is at times irritating, the irritability it causes passes quickly. SD D ? A SA

32. Large airports should be built in isolated areas where people are not likely to build houses. SD D ? A SA

33. There is too much fuss being made over airplane noise. SD D ? A SA

34. When I'm eating, odors from the kitchen are often annoying. SD D ? A SA

35. Many other types of noise are more annoying than aircraft noise. SD D ? A SA

36. Persons living near big airports are probably not bothered by the noise after a while. SD D ? A SA

37. I am to some degree temperamental about small changes in my environment. SD D ? A SA

38. I am annoyed by excessive aircraft noise only occasionally. SD D ? A SA

39. If I lived near an airport, I would stay indoors as much as possible. SD D ? A SA

40. When I travel from a warm climate to a cold one, I have a lot of trouble adjusting. SD D ? A SA

41. Only extremely loud noise from airplanes bother me at all. SD D ? A SA

42. Some of the time aircraft noise makes it very unpleasant to be outdoors. SD D ? A SA

43. Like just about anything, you can get used to aircraft noise if you have to. SD D ? A SA

44. I find that I only notice aircraft noise when it is much louder than normal. SD D ? A SA

45. Even the smallest increase in a noise level, say of a lawnmower, is very annoying to me. SD D ? A SA

46. Aircraft noise only really disturbs me when I'm thinking about a difficult problem. SD D ? A SA

47. When I'm working, I need a controlled environment with no interruption. SD D ? A SA

48. It doesn't take much noise above what I'm used to to disrupt my thinking. SD D ? A SA

SD - Strongly Disagree
D - Disagree
? - Undecided
A - Agree
SA - Strongly Agree

* * *

49.	I am slightly irritated by aircraft noise.	SD	D	?	A	SA
50.	It is doubtful whether excessive aircraft noise is so bad.	SD	D	?	A	SA
51.	Aircraft noise bothers me so infrequently that I don't even consider it a problem.	SD	D	?	A	SA
52.	I can tolerate aircraft noise though it is moderately irritating.	SD	D	?	A	SA
53.	Aircraft noise has very little effect on me in any way.	SD	D	?	A	SA
54.	The best environment for me is one in which there is total quiet.	SD	D	?	A	SA
55.	Although airplane noise is irritating, it probably is not doing any harm.	SD	D	?	A	SA
56.	When I am reading, I prefer only a certain amount of illumination.	SD	D	?	A	SA
57.	I am seldom bothered by the sounds of low flying aircraft.	SD	D	?	A	SA
58.	The constant level of aircraft noise is probably damaging the health of people living near airports.	SD	D	?	A	SA
59.	I am more sensitive to harsh noises than most people.	SD	D	?	A	SA
60.	At work, a change in my environment can really upset my concentration.	SD	D	?	A	SA

APPENDIX E

Annoyance Response Data

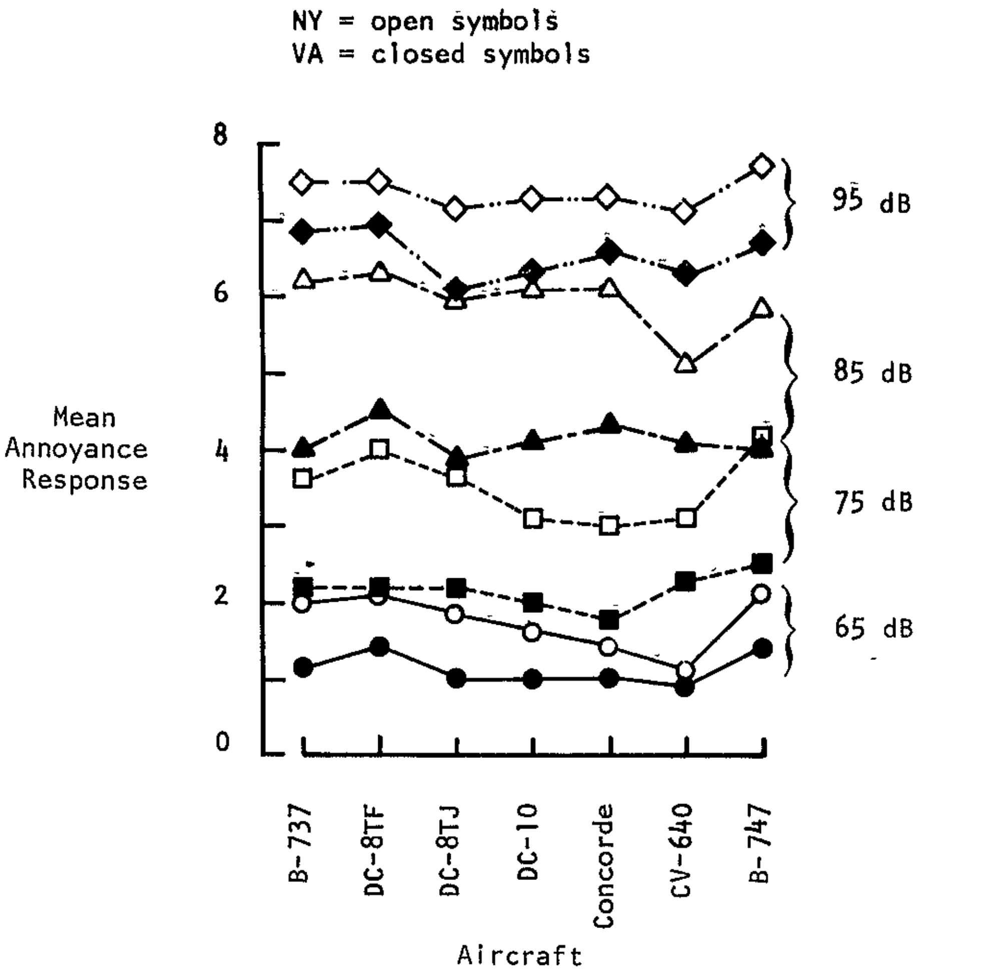


Figure E-1.- Mean annoyance responses for each subject group, for each noise level as a function of aircraft type. The annoyance responses have been averaged across type of operation and subjects.

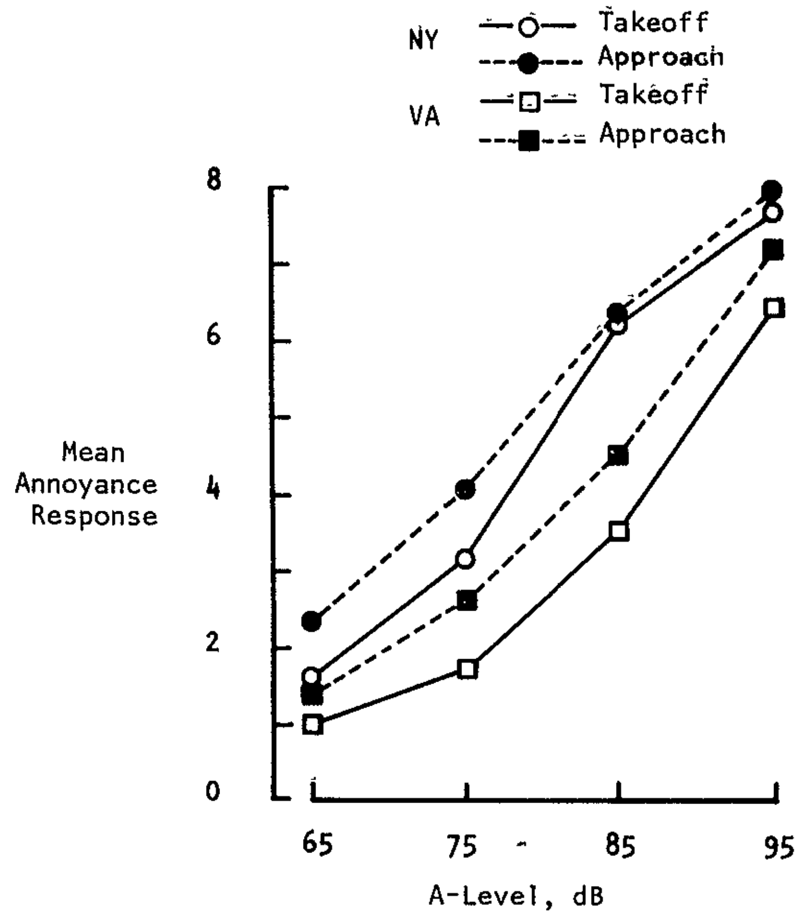


Figure E-2.- Mean annoyance responses for each subject group, for each operation, as a function of A-level for the B-737 aircraft.

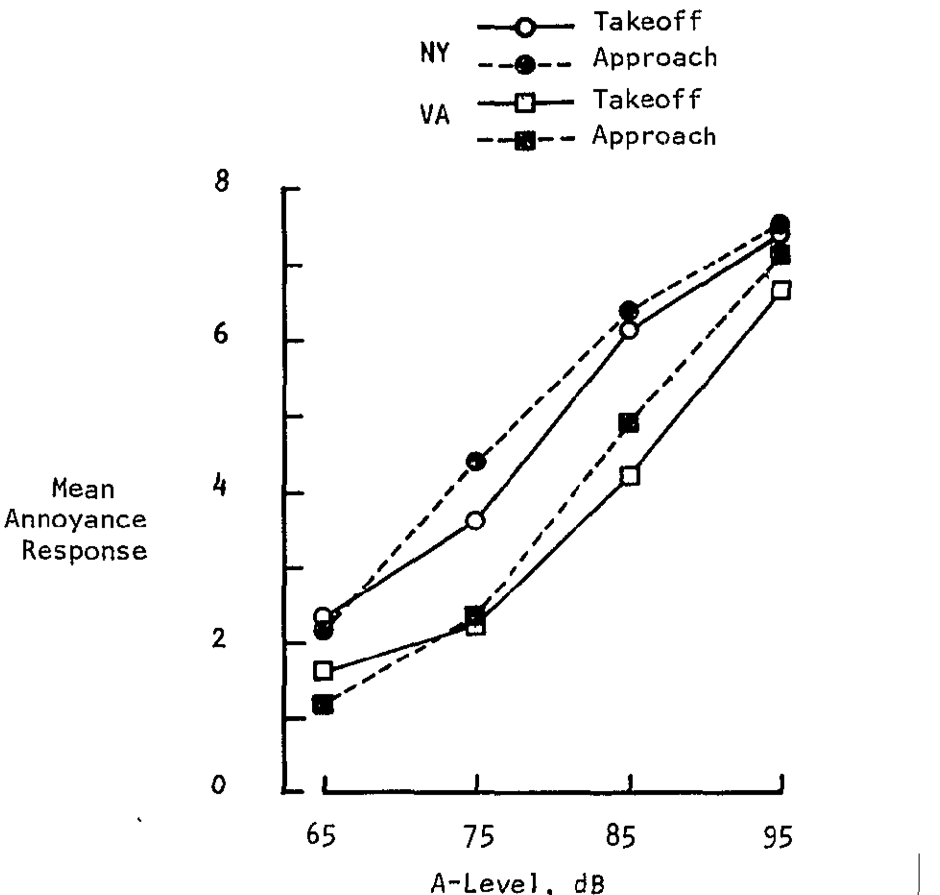


Figure E-3.- Mean annoyance responses for each subject group, for each operation, as a function of A-Level for the DC-8 Turbofan aircraft.

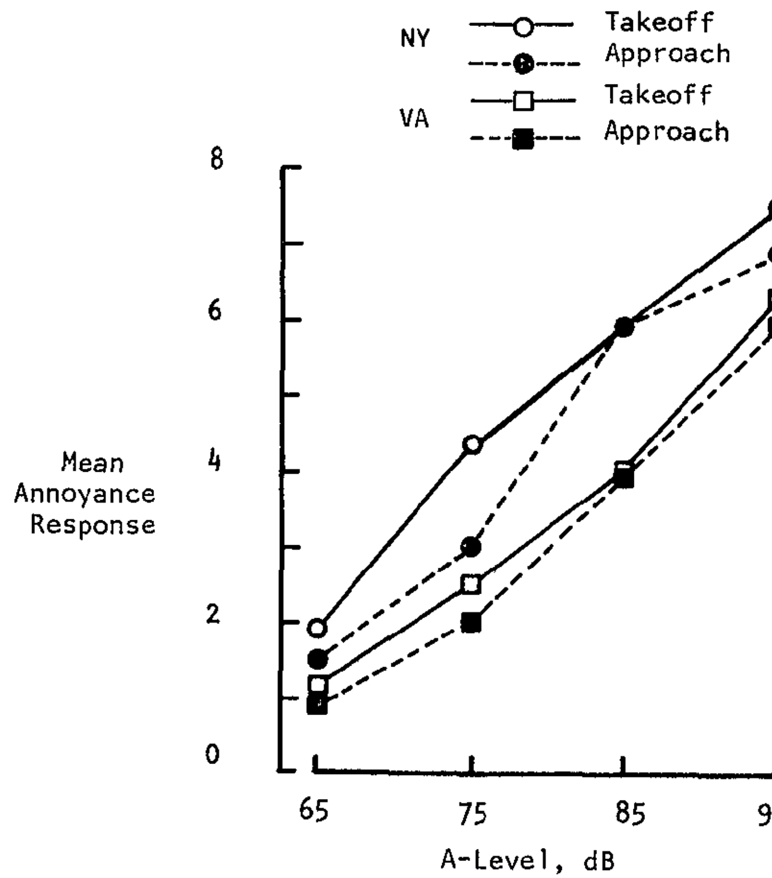


Figure E-4.- Mean annoyance responses for each subject group, for each operation, as a function of A-Level for the DC-8 Turbojet aircraft.

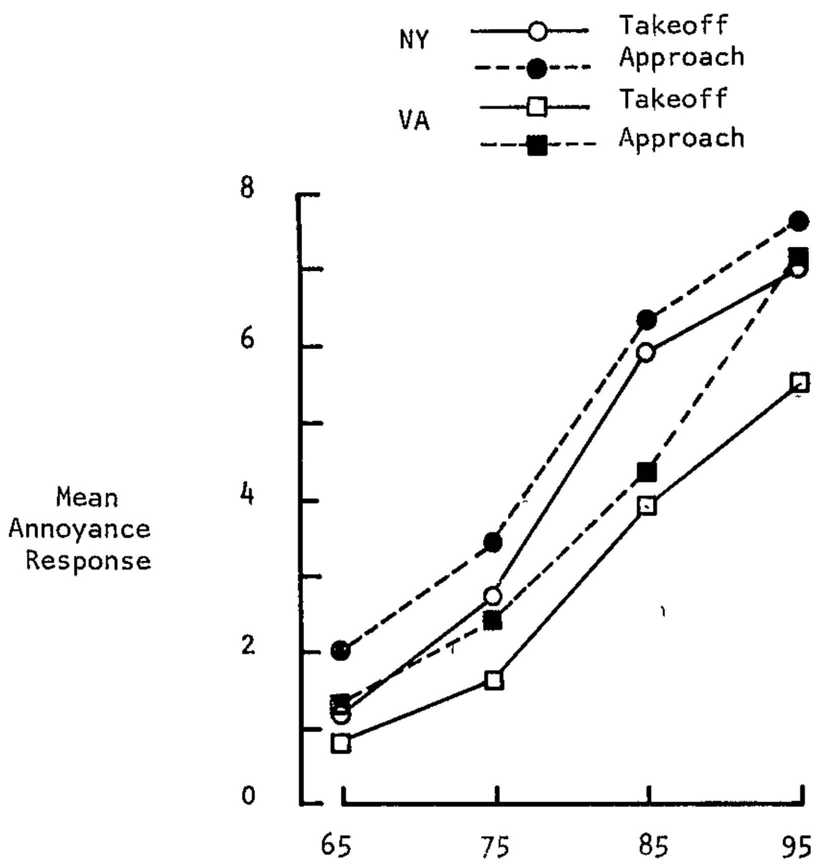


Figure E-5.- Mean annoyance responses for each subject group, for each operation, as a function of A-Level for the DC-10 aircraft.

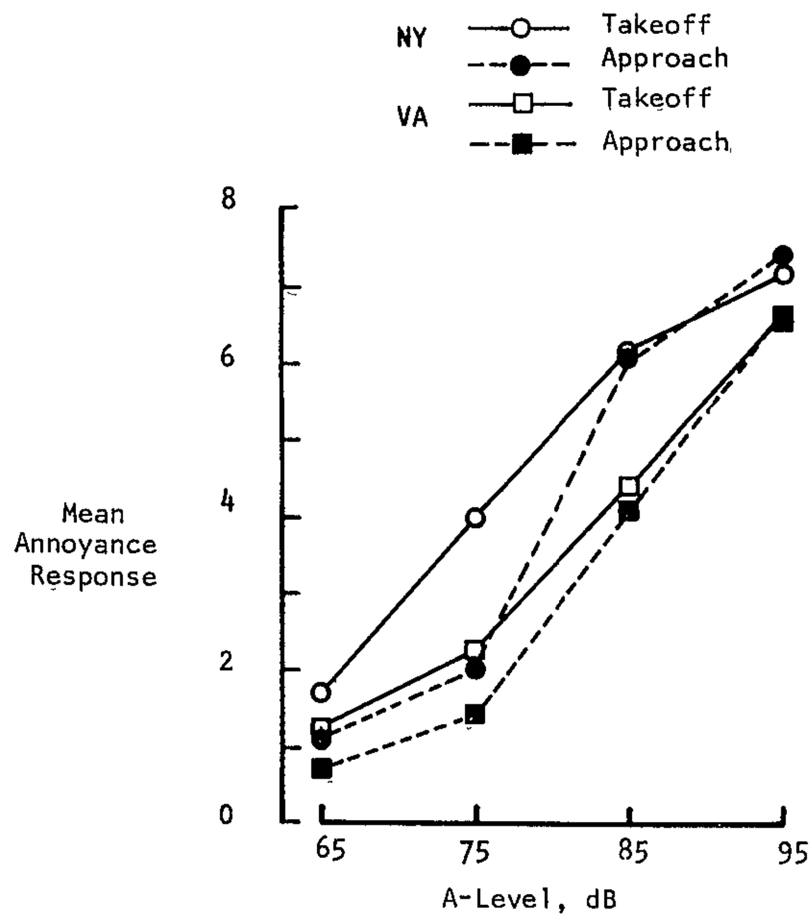


Figure E-6.- Mean annoyance responses for each subject group, for each operation, as a function of A-Level for the Concorde aircraft.

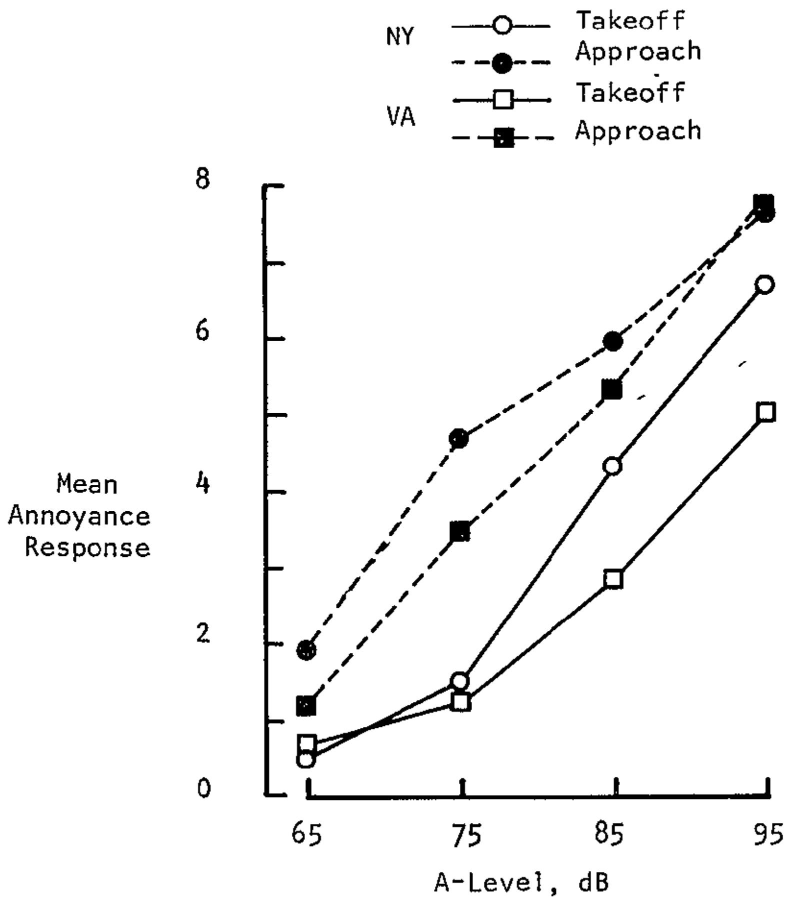


Figure E-7.- Mean annoyance responses for each subject group, for each operation, as a function of A-level for the CV-640 aircraft.

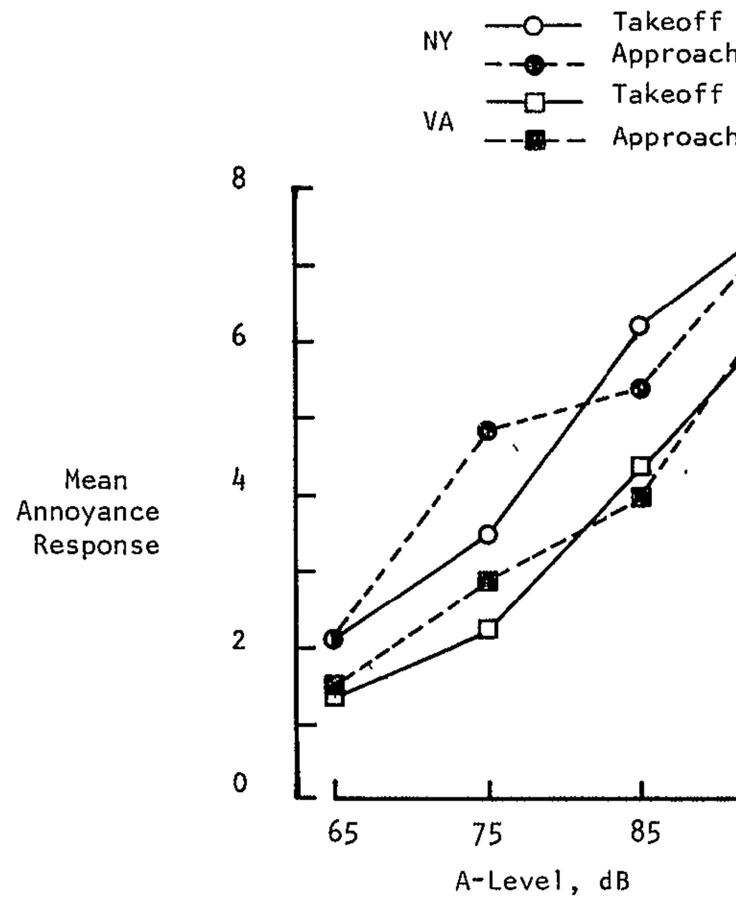


Figure E-8.- Mean annoyance responses for each subject group, for each operation, as a function of A-level for the B-747 aircraft.

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15 Supplementary Notes

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16 Abstract

This paper reports on a study conducted at Langley Research Center for development of an aircraft noise adaptation model which would account for much of the variability in the responses of subjects participating in human response to noise experiments. The principal concept of the model is the determination of an "aircraft adaptation level" which represents an annoyance calibration for each individual. Also given in the paper are the results of a human response to aircraft noise experimental study which utilized subjects from both the Hampton - Newport News, Virginia area and the J. F. Kennedy Airport area of New York City. There was some variability in the annoyance responses of the two groups, with the New York subjects rating a given noise as more annoying than the Virginia subjects. The results of the study indicated that the aircraft noise adaptation model accounted for some of the differences which occur between subjects in making annoyance judgments of noise stimuli. An individual's aircraft noise adaptation level was partially predictable from various attitude-personality variables which account for some of the differences which occur between subjects in making annoyance judgments. The noise level of the stimuli was found to be the single most important parameter in predicting annoyance reactions to aircraft noise.

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